Volume XXX. No. 1 January, 1955

THE JOURNAL OF HORTICULTURAL SCIENCE

(Formerly The Journal of Pomology and Horticultural Science)

Subscription Rates:
SINGLE NUMBERS 15/- EACH
ONE VOLUME (FOUR NUMBERS) 50/- (RATE FOR CANADA & U.S.A., $7.00) POST FREE

PUBLISHED BY
HEADLEY BROTHERS LTD
109 Kingsway London WC2 England

COMMONWEALTH MYCOLOGICAL
15 JAN 1955

THE JOURNAL OF HORTICULTURAL SCIENCE

The suggested abbreviation for the title of this publication is *J. hort. Sci.*

Back numbers of the JOURNAL, together with comprehensive Author and Subject Indexes to Volumes I to X and Volumes XI to XX, are available from the Publishers.

JOINT EDITORS

Prof. T. WALLACE, C.B.E., M.C., D.Sc., F.R.I.C., V.M.H., F.R.S., Horticultural Research Station, Long Ashton, Bristol.

T. N. HOBLYN, Hort. Dip., East Malling Research Station, near Maidstone, Kent.

ASSISTANT EDITOR

W. M. WARE, D.Sc., Brookfield, Wye, near Ashford, Kent.

PUBLICATION COMMITTEE

D. AKENHEAD, O.B.E., M.A., B.Sc., Commonwealth Bureau of Horticulture and Plantation Crops, East Malling Research Station, near Maidstone, Kent.

W. F. BEWLEY, C.B.E., D.Sc., V.M.H., Experimental and Research Station, Cheshunt, Herts.

Prof. W. BROWN, M.A., D.Sc., F.R.S., The Bush, Haddenham, Aylesbury, Bucks.

E. E. CHEESMAN, D.Sc., A.R.C.S., Agricultural Research Council, Cunard Building, 15 Regent Street, London, S.W.1.

M. B. CRANE, A.L.S., V.M.H., F.R.S., Firs Farm, Haughley, nr. Stowmarket, Suffolk.

Sir R. G. HATTON, C.B.E., M.A., D.Sc., V.M.H., F.R.S., 23 Hillside Street, Hythe, Kent.

C. E. HUDSON, N.D.H., V.M.H., Ministry of Agriculture and Fisheries, 1-4 Cambridge Terrace, Regent's Park, London, N.W.1.

F. KIDD, C.B.E., M.A., D.Sc., F.R.S., Low Temperature Research Station, Downing Street, Cambridge.

Prof. E. J. MASKELL, F.R.S., Botanical Department, The University, Edgbaston, Birmingham 15.

Prof. H. W. MILES, D.Sc., Ph.D., Wye College (University of London), near Ashford, Kent.

Prof. J. W. MUNRO, C.B.E., M.A., D.Sc., Frognal Cottage, Larch Avenue, Sunninghill, Berks.

T. NEAME, M.A., V.M.H., Macknade, Faversham, Kent.

J. PHILP, B.Sc., Ph.D., F.L.S., National Vegetable Research Station, Wellesbourne, Warwick.

Prof. R. H. STOUGHTON, D.Sc., V.M.H., The University, Reading, Berks.

F. R. TUBBS, M.Sc., Ph.D., East Malling Research Station, near Maidstone, Kent.

ASSOCIATE EDITORS

F. G. ANDERSSEN, B.Sc., Ph.D., Department of Agriculture, Division of Horticulture, P.O. Box 994, 590 Vermeulen Street, Pretoria, South Africa.

Prof. R. E. D. BAKER, M.A., A.I.C.T.A., Imperial College of Tropical Agriculture, Trinidad, B.W.I.

Prof. B. T. P. BARKER, C.B.E., M.A., c/o Horticultural Research Station, Long Ashton, Bristol.

C. BARNARD, D.Sc., Division of Plant Industry, Council of Scientific and Industrial Research, Canberra City, F.C.T., Australia.

Prof. V. H. BLACKMAN, Sc.D., F.R.S., 17 Berkeley Place, Wimbledon, London, S.W.19.

M. B. DAVIS, B.S.A., M.Sc., Central Experimental Farm, Ottawa, Canada.

K. S. DODDS, D.Sc., John Innes Horticultural Institute, Bayfordbury, Hertford, Herts.

W. C. MOORE, M.A., Ministry of Agriculture and Fisheries, Plant Pathology Laboratory, Milton Road, Harpenden, Herts.

Sir E. J. SALISBURY, C.B.E., D.Sc., L.L.D., F.L.S., V.M.H., V.P.R.S., Royal Botanic Gardens, Kew, Surrey.

Emeritus Prof. E. S. SALMON, F.L.S., Wye College, near Ashford, Kent.

H. V. TAYLOR, C.B.E., D.Sc., A.R.C.S., V.M.H., Preston Grange, Barnet Road, Potters Bar, Middlesex.

L. W. TILLER, B.Sc., Department of Scientific and Industrial Research, Wellington, C.1, New Zealand.

OBSERVATIONS ON THE SHOOT GROWTH OF THE CULTIVATED STRAWBERRY PLANT

By C. G. GUTTRIDGE*
Department of Horticulture, University of Reading

THE investigation was undertaken to give information on the morphological development of the strawberry plant under natural conditions in the field, thus facilitating the planning and interpretation of experiments on the relation of daylength and other environmental factors to growth and development.

No satisfactory or complete description of the growth habit of the strawberry plant *Fragaria Ananassa* Duch. appears to exist in the literature, although many investigations have been carried out to determine the time of inflorescence initiation. Waldo (1930) gives a description of the formation of the inflorescence in the bud, and reports the time of inflorescence initiation for many species of *Fragaria* and a large number of American varieties. The first microscopically visible changes in the growing apex indicating floral initiation were found to occur in September or October in nearly all the summer fruiting varieties he investigated. Roodenburg (1939) found that Deutsch Evern differentiated floral primordia between 8th and 15th September in Holland. Robertson and Wood (1954) have determined the dates of inflorescence initiation of the varieties Sir Joseph Paxton, Royal Sovereign and Auchincruive Climax growing at Mylnefield, Dundee ; there is substantial agreement between their results and those reported here ; in the same paper they analyse the structure of the inflorescence. Mann (1930) describes the early stages in the formation of runner plants, although the paper is mainly concerned with root growth. White (1927) describes some aspects of the anatomy of the strawberry plant. Recently Arney (1953a) has published information on the rate of leaf production, and in another paper (1953b) has described the initiation and growth of leaf primordia in the bud. A preliminary paper by the writer appeared in the Long Ashton Research Station Annual Report for 1951 (Guttridge, 1952).

MATERIALS AND METHODS.

Certified runner plants of the varieties Royal Sovereign (M.40 clonal stock), Perle de Prague and Auchincruive Climax were planted in the field in April, 1951 at Long Ashton Research Station. These plants (F51 series) provided sample plants for dissection during 1951 as first-year plants (having passed through one winter). In addition, second-year Climax plants (S51 series), planted March, 1950, were available. During summer the F51 series of all three varieties were allowed to form runner trains, and each young runner plant was labelled with the date of rooting, which coincided approximately with the expansion of the first, or the emergence of the second true leaf of the runner plant. The stolons were not severed.

Although most of the work was done on the above series, further observations were made in 1952 and 1953 at the Horticultural Research Laboratories of Reading University at Shinfield, Berks. Second-year Climax plants were taken during these

* Now of the Scottish Horticultural Research Institute, Mylnefield, Invergowrie, By Dundee.

years from a commercial plantation on the University Horticultural Station (S52 and S53 series). First-year Climax and Sovereign plants were available from a spring-planted series in 1952 (F52 series) and from an autumn-planted series in 1953 (F53 series). The plants received no special treatments and were not deblossomed.

During 1951, at Long Ashton, sample plants from the F51 and S51 series were lifted at intervals of up to four weeks. The leaf-blades and roots were removed and, after washing, the crowns were fixed and preserved in 70 per cent. methylated spirits or in a formalin-acetic-alcohol mixture until required for dissection under the binocular dissecting microscope.

The latitude of both Long Ashton and Shinfield is approximately 51° 25′ N.

The plastochron is used to indicate the approximate rate of development of various plant structures in terms of the rate of leaf production. In applying this unit to leaf production in the strawberry, Arney (1953a) defined it as the time interval between the formation of successive leaf primordia on the apex, or as the time interval between emergence of successive leaves from the bud. The difference between the two criteria is not great and for the purposes of this paper is not important.

A leaf is considered to have emerged when its laminae are clear of the stipules of the next older leaf.

Morphological development

A strawberry plant consists of a number of crowns, each of which grows leaves, runners, branch crowns, inflorescences and adventitious roots.

The crown forms a suitable descriptive unit and, in fact, appears to be able to function as an independent unit on the plant. The data collected have been generalized to form the following descriptions but, where there were marked variations between crowns, plants or varieties, it is noted in the text. Some 600 crowns in all were dissected.

1. *Leaf formation.*

Each crown has a number of leaves at various stages of development, arranged spirally on the axis. The base of a well-developed crown is protected by the decaying sheathing stipules of dead leaves. Above these are the mature green leaves also with protective stipules. Within the enclosing sheath of the stipules of the last emerged leaf, and therefore enclosed within the bud, are 5 or 6 developing leaves. This number is remarkably constant throughout the year, although, as Arney (1953b) notes, there is a tendency for the number to rise by one in winter and to fall to a little below normal in spring. Differences between these figures and those of Arney (1953b) can be attributed to the different criteria of emergence.

The last formed leaf primordium can first be detected under the dissecting microscope as a slight ridge on the otherwise domed growing point. At approximately half a plastochron from the small ridge stage (hereafter referred to as the time of inception) the development of three growing points on the leaf primordium can first be seen. Each tip develops into a leaflet. After one plastochron the division into three and also the early development of the stipules of the leaf are clearly visible.

Leaf blades and stipules continue growth and the leaf emerges in its turn from the sheathing stipules of the next older leaf some 5 to 6 plastochrons from its inception on the growing point. All younger developing leaves are enclosed within its stipules.

The leaf emerges, unfolds and expands over a period of approximately two plastochrons, so that the next leaf emerges well before the laminae of the lower leaf reach full expansion.

2. *Growth of axillary buds.*

The axillary growing point can be identified at one and a half to two plastochrons from the inception of its subtending leaf. It appears as a small, smooth, slightly raised area. The axillary bud may develop into a stolon or a branch crown bud, and differentiation probably occurs during the formation of the first two internodes. The tissue below the first node is described as the first internode.

(*a*) *Early development of stolons.* A stolon is a specialized branch. It differs from a branch crown principally in the extensive elongation of the first two internodes. A similar elongation of any but these two internodes has not been observed.

A developing stolon can usually be identified as such under the dissecting microscope at the two-leaf-primordia stage and possibly before this. Its subtending leaf will then be some four plastochrons from its inception. Comparison with a developing branch crown bud, also at the two-leaf-primordia stage, shows that the first internode of a stolon bud is longer than the first internode of a branch crown bud.

The young stolon emerges from the sheathing stipules of its subtending leaf as the leaf unfolds and expands. At this stage the apex usually shows two scale leaf and two true leaf primordia. Elongation of the first two internodes continues and as the stolon approaches full length the third leaf—the first true leaf—emerges from the sheathing stipules of the second scale leaf. As the third and fourth leaves—first and second true leaves—unfold, adventitious roots begin to break through the surface of the stem near the second node. At this stage (" rooting ") the young stolon has the normal complement of five or six developing leaf primordia within the bud. The young runner plant then quickly establishes itself.

The last stolon to develop in any one season sometimes fails to attain full length, but remains some five or ten centimetres long and is thick and fleshy. This type of modification was seen more frequently on experimental plants in the glasshouse than on plants in the field.

Two or three of the axillary buds on the main axis above the last stolon commonly develop as branch crowns with their first internodes thickened and elongated to one or two centimetres. The elongated internodes of these intermediate structures are more or less hidden by the sheathing stipules on the subtending leaf on the main axis.

(*b*) *Development of axillary buds on the young stolon.* Axillary growing points can be seen on the young stolon before it has emerged from the parent crown. At the time the stolon emerges, growing points in the axils of both the first and second scale leaves are present and each has one or two leaf primordia, the second being no more than a ridge on the growing point. Both these axillary buds differ from buds developing in the axils of later, true leaves. The bud at the first node may either remain dormant or develop as a stolon, forming a branch on the stolon axis.

The bud in the axil of the second scale leaf, which is at the base of the young stolon plant, develops very rapidly and in this respect differs from later formed axillary buds. It is this bud that forms the continuation stolon (Robertson and Wood, 1954) in a runner train. It emerges from the protection of the sheathing stipules of its subtending scale leaf as the primary stolon attains full length and before root initials appear.

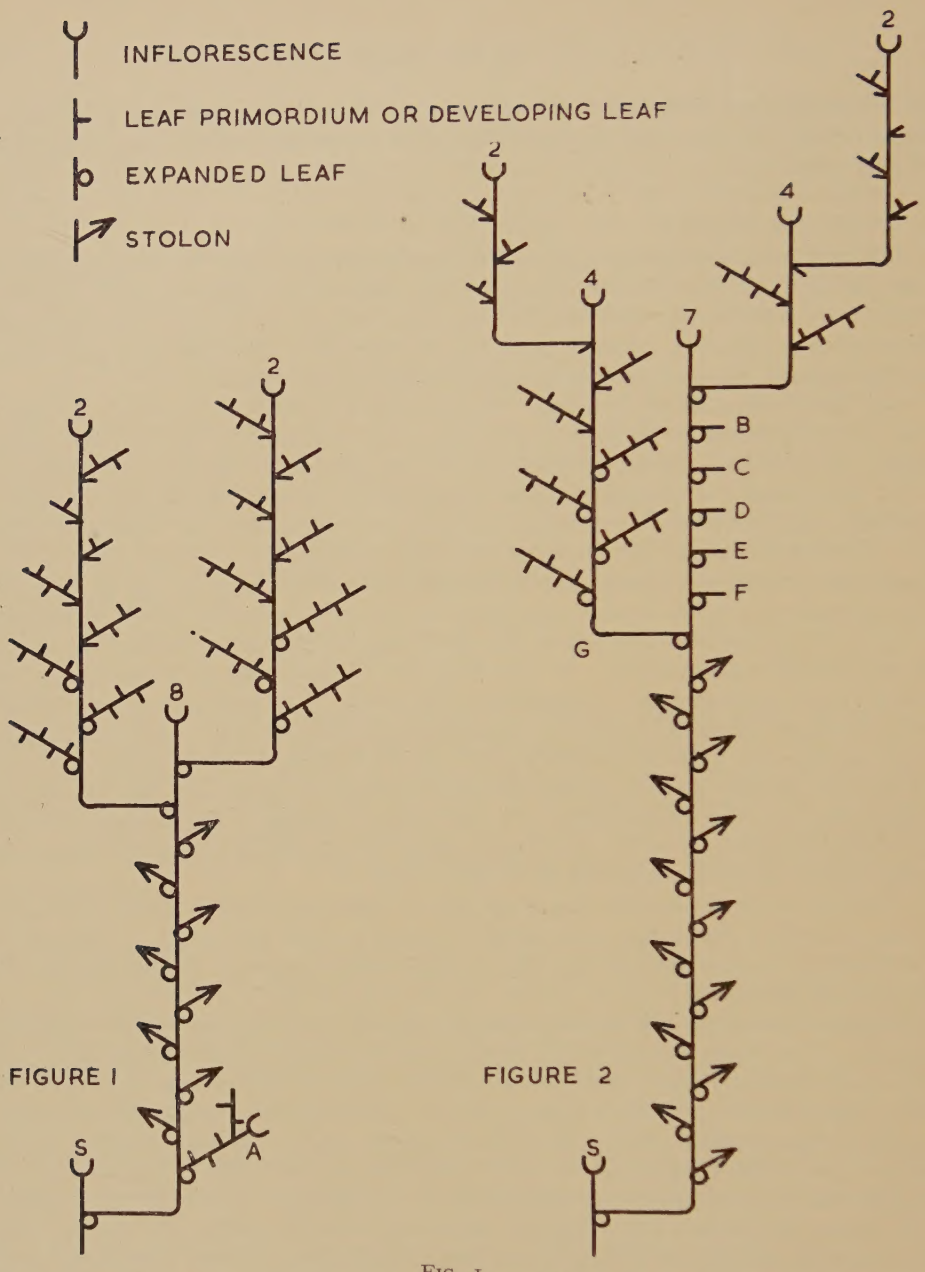

FIG. 1.

A diagram of a large crown of an Auchincruive Climax plant of the F51 series lifted on 1/10/51.

FIG. 2.

A diagram of a large crown of a Royal Sovereign plant of the F51 series lifted on 2/1/52. Branch crowns at B, C, D, E and F were similar to the branch crown G, but of decreasing size toward the apex.

In both diagrams leaves are arranged alternately or otherwise for convenience of representation. The structure of the principal axes and of the lateral growths arising on them is shown, while higher order laterals are omitted for clarity.

Inflorescences labelled " S " flowered in the spring of 1951. Stages of development (based on those of Waldo (1930)) of other inflorescences are indicated by numbers, thus : Stage 2, Primary flower with sepal but no petal initials ; Stage 4, Pistil initials covering central dome of the receptacle of the primary flower; Stage 7, Inflorescence about to emerge; Stage 8, Flowering.

(*c*) *Early development of branch crown buds.* When environmental conditions are unfavourable for differentiation of the axillary buds into stolons, they develop as branch crown buds. A distinction is made between branch crown buds (incipient branch crowns) and mature branch crowns which have grown out.

As described previously, the axillary bud is discernible in the axil of a leaf primordium when the latter is some one and a half to two plastochrons from its inception. Leaf primordia develop on the axillary bud at about the same rate as on the growing point of the main axis, so that by the time the subtending leaf unfolds the axillary bud has about four leaf primordia. These buds differ from stolon buds in the absence of appreciable stem tissue between the nodes, and also in the less precocious development of the bud in the axil of the second leaf primordium.

The first (lowest) leaf primordium on the branch crown bud develops only a small leaf blade and may be almost alaminate, although the stipules are large and sheathing. Similarly, the blade of the second leaf is reduced, although not so markedly as the first. The final size of the laminae of the first two leaves depends on the position of the branch crown in relation to terminal inflorescences on the main axis. The nearer a branch crown is to a morphologically higher inflorescence, the larger are the laminae of the first two leaves. The first two leaves on the axillary bud immediately below the terminal inflorescences of the crown are nearly normal in shape and size. The further growth of branch crown buds is described below.

Axillary buds form on the stems of branch crown buds, but their growth presents no features of special interest.

3. *Inflorescence initiation and development.*

The inflorescence develops terminally (Fig. 1). Inflorescence initiation is considered to have taken place when the apical growing point has elongated and its top has become somewhat flattened. This stage was not often seen and probably is of short duration. Soon after this the first indications of the development of secondary flowers can be seen. A later stage, where sepal primordia of the primary flower are developing round the rim of the flattened top, was observed more frequently.

The branch structure of strawberry inflorescences shows great variety of form and some variations can be seen in the developing inflorescence at an early age. The development and structure of inflorescences have been described by Waldo (1930), Darrow (1929) and Robertson and Wood (1954).

The inflorescence emerges from the protection of the sheathing stipules of the leaf immediately below it at about the time the leaf expands. Limited variation in the relative times of emergence of leaf and inflorescence has been observed, especially under experimental conditions in the glasshouse.

4. *Effect of the inflorescence on the formation of branch crown buds.*

The presence of the terminal inflorescence on a crown is associated with a change in the rate of growth of the three or four axillary buds immediately below it. In Royal Sovereign, under field conditions, these buds were all found to be branch crown buds, stolon differentiation having ceased previously (Fig. 2). Climax in the field, and both varieties under experimental conditions in the glasshouse, sometimes continued stolon differentiation, for a time at least, while inflorescence formation was taking place. This is shown by the morphological proximity of stolons and inflorescence in Fig. 1, in contrast to the condition shown in Fig. 2. The axillary bud immediately below an inflorescence on an established plant has never been observed

by the writer to develop into a stolon, although it occasionally develops into an inflorescence without further leaf production.

Extension growth of the crown continues along the axis of the uppermost lateral bud below the terminal inflorescence (hereinafter called the crown extension axis), thus giving a sympodial structure to the crown which is not at first sight apparent (Guttridge, 1952 ; Arney, 1953b ; Robertson and Wood, 1954). Under environmental conditions favourable to floral induction, a crown extension axis typically forms three or four nodes before its vegetative growth is terminated by the initiation of a further inflorescence (Fig. 2).

TABLE I.

Date of first inflorescence initiation.

Series	Date lifted	No. of crowns dissected	No. vegetative	No. doubtful	No. with inflor. initials	No. at Stage 1	No. at or beyond Stage 2
Royal Sovereign. F51 series. First-year plants	4/9/51	4(4)	3	1	0	0	0
	13/9/51	5(4)	1	0	4	1	3
	27/9/51	9(4)	2	0	7	0	7
Royal Sovereign. F52 series. First-year plants	1/9/52	4(2)	3	1	0	0	0
	6/9/52	12(6)	4	4	4	4	0
	11/9/52	11(5)	5	2	4	3	1
	24/9/52	15(3)	0	0	15	1	14
Perle de Prague. F51 series. First-year plants	10/9/51	9(4)	8	0	1	0	1
	13/9/51	3(3)	1	0	2	0	2
	27/9/51	6(4)	0	2	4	2	2
Climax. F51 series. First-year plants	10/7/51	7(6)	6	1	0	0	0
	24/7/51	6(2)	2	0	4	0	4
	31/7/51	3(2)	3	0	0	0	0
	10/8/51	10(4)	4	0	6	0	6
Climax. F52 series. First-year plants	12/7/52	8(8)	4	3	1	1	0
Climax. F53 series. First-year plants	23/6/53	7(6)	3	1	3	3	0
Climax. S51 series. Second-year plants	6/7/51	6(1)	5	1	0	0	0
	24/7/51	13(4)	2	0	11	2	9
	8/8/51	10(3)	3	0	7	0	7
Climax. S52 series. Second-year plants	2/7/52	7(2)	0	0	7	0	7
	4/7/52	15(8)	0	0	15	0	15
Climax. S53 series. Second-year plants	15/6/53	4(4)	1	1	2	2	0
	22/6/53	9(9)	0	2	7	6	1

Figures in brackets indicate the number of plants from which the preceding number of crowns were taken for dissection.

Stage 1. Axis elongated, but no sepal initials present.

,, 2. Sepal but no petal initials present on primary flower primordium.

5. *Time of inflorescence initiation.*

The features of the growth habit so far discussed did not vary much between varieties or crowns, or between plants of different ages or growing under differing environments. The season of flower initiation, however, and the season and position

of branch crown formation are determined by environment, size of plant and variety.

The criterion of inflorescence initiation was described above. The Table* summarizes the data on the time of inflorescence initiation.

(*a*) *Royal Sovereign.* Inflorescence initials were first present during the first fortnight of September in both 1951 and 1952. Similar data for runner plants cannot be so easily abridged. Although not conclusive, they indicate that runner plants rooting before September have inflorescence initials from about the same time as their mother plants. Runners rooting during September form initials about the time of rooting, and later rooting runner plants commence initiation before rooting but later than older plants. Mother plants and older runner plants were usually found to have second order inflorescences by the time of dormancy, and a few crowns had third order inflorescences.

(*b*) *Perle de Prague.* Fewer plants of this variety were dissected but the data suggest that inflorescence initiation commenced at about the same time as in Sovereign in 1951.

(*c*) *Climax.* The earliest occurrence of inflorescence initiation was recorded in the second-year plants in 1953, when initials were found in mid-June. In 1952 Stage 1 (see Table I) was missed but initials at Stage 2 were found consistently on 2nd and 4th July. The records for 1951 are variable. Dissections later in autumn showed that there was considerable variation in the stages of development of inflorescences (and therefore presumably in time of initiation) from crown to crown, especially in the first-year series. This may have been partly due to the spring transplanting of the first-year plants.

In runner plants inflorescence initiation does not occur until August even in the earlier-formed runner plants (rooting 17/7/53). The later initiation in runner plants, compared with mother plants, is reflected in the later emergence of first order inflorescences which was observed in the field.

The early-formed inflorescences of Climax emerge and flower in August and September, while the second and third order inflorescences initiated in late summer and autumn give rise to the summer crop the following year.

These data are in substantial agreement with those of Robertson and Wood (1954), working at Dundee.

6. *Initiation of inflorescences on branch crown buds.*

Inflorescence initiation does not normally occur on branch crown buds before it has taken place on the primary axis. The development of branch crown buds up to the 3 or 4 leaf stage has already been described. If inflorescence initiation has taken place on the primary axis of the crown, then terminal inflorescences commonly develop on branch crown buds at this stage or soon after. In the absence of inflorescence initials on the primary axis, initiation is delayed on the branch crown buds, and more than 3 or 4 leaf primordia are formed below the inflorescence. In the F51 series of Sovereign plants some of the lower branch crown buds above the last stolon formed 6 or 7 leaf primordia before initiating an inflorescence (Fig. 2. G). In Climax runner plants as many as 8 or 10 leaf primordia were sometimes formed on similar buds. In general the number of leaf primordia formed on the lower branch crown

* Full data are contained in a thesis entitled "The Influence of some Environmental Factors on the Initiation of Flowers and Runners in the Strawberry Plant", which was submitted in 1953 by the writer for the degree of Ph.D. at Reading University.

buds before inflorescence initiation apparently depends on the rate of growth of the bud and on the relative times of inflorescence initiation and of cessation of stolon formation. Inflorescences terminating axillary axes of two nodes only were occasionally seen. Growth of branch crown buds is continued above the inflorescence by crown extension axes as described before. Usually all buds except those with less than 3 or 4 leaf primordia have inflorescence initials by the time the plants go dormant in late autumn.

7. *The commencement and cessation of stolon production.*

The position on the axis of the first lateral bud to develop into a stolon in spring depends on the position of inflorescences in the bud. It was observed (especially in pot-grown plants in 1952 and 1953) that the buds subtended by the two lowest leaves on the crown extension axis above the last-formed inflorescence commonly developed into the first stolons of the season. Occasionally axillary buds below the last-formed inflorescence were differentiated into stolons. It is clear that stolon differentiation commences early in the year and probably the first axillary bud to undergo differentiation in spring becomes the first stolon.

In the F51 series stolons of all three varieties were subtended by nearly all the spring and summer leaves. The second-year Climax plants produced runners less freely, and some branch crown buds were formed where stolons might have been expected. This may be common in large plants and may be associated with, among other things, inter-crown competition and a heavy crop.

Stolon and branch crown buds could not be distinguished with certainty by dissection during the early stages of differentation, particularly at about the time of cessation of stolon formation, due to the formation of intermediate structures as already described. The time when stolon differentiation ceased could not, therefore, be ascertained accurately by direct observation. It is clear, however, from the data on the F51 series of Sovereign plants that axillary buds first ceased to pass through the early stages of stolon formation some time in August. A similar critical stage was reached in first-year and second-year Climax plants in July, 1951. Developing stolons in the bud continued to emerge for a further one or two plastochrons.

Some abnormal stolons were produced by the second-year Climax plants in 1951. This was typified by the presence of an inflorescence terminating the stolon axis after the formation of two nodes only. Both these nodes had stolon buds, so a runner plant could not develop at the second node in the normal manner. Usually, but not invariably, the abnormal stolon was the last stolon to form on the crown in that season. The inflorescences did not make an important contribution to the autumn flowering.

8. *Plant enlargement by crown multiplication.*

In vigorously growing young plants most branch crown buds are differentiated during the period between the cessation of stolon differentiation and dormancy. Branch crown buds develop fairly consistently until their subtending leaves emerge, when they usually have 4 nodes. At this stage they are likely to form a terminal inflorescence if initiation has commenced at the crown apex. Soon after the 4-node stage, differences in the rate of growth of branch crown buds were observed ; some buds continued to produce leaf primordia at much the same rate as the main axis, while others on different crowns grew more slowly. In the first instance the buds developed into branch crowns more or less immediately (Fig. 2. G), while, in the

second, the buds remained small and hidden among the leaf bases (Fig. 1. A). Such small buds are available for branch crown formation later and may develop if environmental conditions permit and there are insufficient recently-formed branch crown buds.

Immediate growth of buds into branch crowns was observed in the runner plants of all three varieties rooted in July and August. The branch crown buds continued to form leaf primordia at a similar rate to the main crowns. The leaves eventually emerged and expanded, so that new crowns were formed the same autumn or the following spring when growth recommenced. It was not always the earliest (lowest) branch crown that attained the greatest size by winter. Not infrequently the first one or two lateral buds above the last stolon remained small, while later-formed buds developed and attained the greatest size by winter. This may have been associated with the change from stolon to branch crown bud formation. Sometimes the bud above the last stolon to emerge was an aborted stolon.

On the later rooting runner plants the axillary buds mostly remained small and hidden beneath the sheathing stipules of leaves on the main crown. The rate of leaf initiation on these slow-growing buds was much less than on the main axis. A similar slow-growing condition was never observed in stolon growth. Inflorescence initials were formed on the slow-growing buds after the formation of about four leaf primordia, as before, but these also were small and developed slowly through the autumn. They were often more or less distorted. The growth of the runner plants could not be followed in the succeeding spring.

Similar slow-growing branch crown buds were frequently seen on the second-year Climax plants which were already large and many-crowned. Some of these buds produced small inflorescences in spring, but did not develop into branch crowns. The inflorescences contributed little to the crop.

Plants of all three varieties of the F51 series occasionally formed branch crowns through the summer from buds which had apparently remained slow-growing during the previous autumn and spring and had become hidden among decaying leaf bases low on the main crown. Owing to uninterrupted stolon formation these were the only buds available for crown multiplication during the summer. Possibly some branch crown formation would have occurred in spring were it not for the set-back associated with spring transplanting. Further branch crown formation took place in autumn, 1951, from newly-formed buds (Fig. 2. B–G).

In the second-year Climax plants, studied in 1951, branch crown multiplication resulted almost entirely from the growing out of the second branch crown buds below the terminal inflorescences. The first buds became the crown extension axes. This habit of branching (Fig. 1) occurred very commonly in all series and varieties. The buds grew out at the time or soon after the inflorescences above them emerged. Inflorescences on those buds which grew out matured and fruited.

The behaviour of plants both in the field and under various experimental environments indoors suggests that the development of buds into branch crowns depends, not so much on specific requirements of daylength or other formative factors, but rather on quantitative relationships between the plant and its environment. Crown multiplication appears to be influenced by such factors as plant size, both in itself and in relation to its environment, and by the vigour of growth, which in turn is dependent on the environmental conditions. The formation and maintenance of young runner plants during the summer affects crown multiplication by cutting off

the supply of newly-formed branch crown buds and probably also by the competitive suppression of growth of buds already present low on the crown.

It is concluded that buds will grow out into branch crowns more or less immediately, if conditions are favourable to an increase in plant size during the time when newly-formed branch crown buds are present. This time is limited, in vigorously growing plants, to the period between the emergence of the last stolon from the bud in late summer or autumn and the emergence of the first stolon in spring, which approximately coincides with flowering. The influence of modifications of daylength and temperature upon the phenomena of inflorescence and stolon initiation and growth will be the subject of later papers.

SUMMARY.

A description is given of the growth and development of the strawberry varieties Royal Sovereign, Auchincruive Climax and Perle de Prague growing outdoors at Long Ashton and at Shinfield, Berks.

Growth is sympodial and inflorescences are formed terminally. Inflorescences were found to be first initiated each year in June or July in Auchincruive Climax and in early September in Royal Sovereign and Perle de Prague. Further inflorescences are initiated terminally during late summer and autumn on the crown extension axes, which are subtended by leaves immediately below inflorescences. By dormancy in late autumn all axes, except small ones with less than 3 or 4 leaf primordia, are likely to have developing inflorescences. The first formed inflorescences on Climax plants emerge and flower in August and September. Later-formed inflorescences of Climax and all those of Royal Sovereign and Perle de Prague normally remain in the bud until spring when they emerge, flower and fruit.

Axillary buds develop into either stolons or branch crown buds. It is probable that the first axillary bud to become differentiated in spring becomes the first stolon to emerge in summer. Stolons emerge from the crown as their subtending leaves unfold and expand. Under good growing conditions differentiation and the early stages of stolon formation continue until about the time of inflorescence initiation in Climax and until August in Royal Sovereign. Young stolons in the bud continue to emerge for a further one or two plastochrons.

Branch crown buds are formed during the period commencing with the cessation of stolon differentiation and ending with dormancy, or at other times when stolon formation fails. Branch crown buds present on the plant may grow out into branch crowns at any time of the year, but most commonly do so in autumn and spring when the plants are not primarily engaged in producing and supporting young runner plants. Observation suggests that the growing out of branch crowns is dependent upon general vigour rather than upon specific requirements of daylength or other climatic factors.

ACKNOWLEDGMENTS.

The author wishes to express his thanks to Professor R. H. Stoughton for his supervision of the investigation, and for permission to publish this paper ; also to Dr. L. C. Luckwill for his supervision of the field work at Long Ashton and to Mr. R. D. Reid of Auchincruive, for providing unpublished data on the variety Auchincruive Climax.

REFERENCES.

Arney, S. E. (1953a). Studies in growth and development in the genus *Fragaria*. I. Factors affecting the rate of leaf production in Royal Sovereign strawberry. J. hort. Sci., **28,** 73.

——— (1953b). The initiation, growth and emergence of leaf primordia in *Fragaria*. Ann. Bot., Lond., N.S. **17,** 477.

Darrow, D. M. (1929). Inflorescence types of strawberry varieties. Amer. J. Bot., **16,** 571.

Guttridge, C. G. (1952). Inflorescence initiation and aspects of the growth habit of the strawberry. Ann. Rep. Long Ashton Res. Sta. 1951, 42.

Mann, C. E. T. (1930). Studies in the root and shoot growth of the strawberry. V. The origin, development and function of the roots of the cultivated strawberry. Ann. Bot., Lond., **44,** 55.

Robertson, M., and *Wood, C. A.* (1954). Studies in the development of the strawberry. I. Flower bud initiation and development in early- and late-formed runners in 1951 and 1952. J. hort. Sci., **29,** 104.

Roodenburg, J. W. M. (1939). Het vervroegen van aardbeien met kunstlicht. Landbk. Tijdschr., **51,** 896.

Waldo, G. F. (1930). Fruit bud development in strawberry varieties and species. J. agric. Res., **40,** 393.

White, P. R. (1927). Studies in the physiological anatomy of the strawberry. J. agric. Res., **35,** 481.

(*Received* 14/5/54.)

THE EFFECTS OF CHLORDANE AND TOXAPHENE ON MITOSIS IN ROOTS OF THE ONION *(ALLIUM CEPA* L.*)*

By MARY E. SCHOLES

Elsenham, Bishop's Stortford, Herts.

SYNOPSIS.

Experiments were carried out with technical chlordane and toxaphene to ascertain whether, employed as insecticides, they had any effect on cell division. Root-tips of onion seedlings were used as test material and the doses used were equivalent to 20 and 200 lb. per acre of 10 per cent. dusts on gypsum. By germinating onion seeds in direct contact with the insecticide under investigation, it was shown that neither chlordane nor toxaphene affected germination, but chlordane reduced the growth rate. The frequency of nuclear divisions was unaffected by toxaphene, but reduced by chlordane. Both compounds affected the dividing cell by causing a delay in pro-metaphase and preventing nuclear reconstruction in telophase. In addition, chlordane had a lethal effect on the resting cell. The effect on telophase was evident for a period of at least four days after removal from the insecticides.

Pot experiments showed that the low dose of toxaphene had little effect on cell division, but the low dose of chlordane and the high dose of both compounds affected a large proportion of the roots examined.

Technical chlordane was separated into three fractions and each fraction was tested separately for its effect on cell division. Samples of *gamma* chlordane and technical and purified heptachlor were also tested. These tests showed that one fraction of chlordane, which comprised the bulk of the material, caused the derangements in the dividing cell and similar derangements were caused by heptachlor. It is most probable that these are the compounds which determine the insecticidal properties of chlordane. A lethal effect was caused by another small fraction, the removal of which, on a commercial scale, would greatly reduce the phytotoxic effects of chlordane without reducing its insecticidal properties. Attention has been drawn to the fact that chlordane and toxaphene do not cause polyploidy ; an important difference from BHC.

Introduction.

Brown (1951) has reviewed the literature on the uses of both chlordane and toxaphene as insecticides, and discussed their properties. A number of workers have reported phytotoxic effects of both these compounds, viz. Morrison *et al.* (1948), Turner and Woodruff (1948), Cullinan (1949) and others. Brown (1951) has stated that the appreciable volatility of chlordane reduces the hazard of toxic residues on crops by ensuring that they are reduced to negligible proportions in two weeks. Cullinan (1949), however, considered that chlordane was stable in the soil and that the problem of accumulation was common to chlorinated hydrocarbon insecticides, except toxaphene, which breaks down under certain conditions. Casida and Allen (1952) suggested that both chlordane and toxaphene penetrated into the tissues of the plant, although their very low water solubilities made translocation in large amounts improbable.

The chlorinated hydrocarbons are becoming increasingly important in the control of pests on plant foods in the colonies and toxaphene is now being tried on a larger scale in this country for the control of apple sawfly in orchards at the time of total petal fall. A previous investigation, Scholes (1953), showed that *gamma* BHC (hexachloro*cyclo*hexane) induced polyploidy and other cytological derangements

which were too important genetically to be ignored. It was, therefore, thought to be useful to investigate the possibility of toxaphene and chlordane also causing similar derangements.

THE INSECTICIDES.

The recommended application of chlordane and toxaphene for the control of a variety of insects is at the rate of 1–2 lb. of actual insecticide per acre. They may be applied as a dust or sprayed in the form of an emulsion diluted with water. In these experiments technical toxaphene, chlordane, fractions of chlordane obtained by chromatographic separation and samples of technical heptachlor (m.p. 63°–76° C.), purified heptachlor (m.p. 91°–93° C.) and *gamma* chlordane (m.p. 102°–104° C.) were used as 10 per cent. dusts on gypsum. Technical heptachlor and *gamma* chlordane were obtained from the Velsicol Corporation and purified heptachlor was obtained by Dr. A. H. M. Kirby of East Malling Research Station from technical heptachlor by dissolving the material in petroleum ether, b.p. 60°–80° C., passing the solution through an alumina column and finally crystallizing from the same solvent. The compound under investigation was dissolved in acetone, poured onto the gypsum, the acetone allowed to evaporate and the mixture turned in a " butter churn " for thirty minutes. Table I shows the doses used. They were chosen to cover normal doses and possible heavy concentrations or accumulations in the field.

TABLE I.

Range of doses of insecticides used.

gm./Petri dish or pot compound on gypsum	lb./acre actual compound	lb./acre compound on gypsum
0·015	2	20
0·15	20	200

CHROMATOGRAPHIC SEPARATION OF CHLORDANE.

Chordane was separated into four fractions by an adaptation of the technique used by March (1952).

An aluminium oxide adsorption column was prepared and saturated with the solvent, petroleum ether, b.p. 40°–60° C. The chlordane was dissolved in further petroleum ether and added to the top of the column. A yellow fraction ran through rapidly, leaving other coloured material at the top. Further elution with 1 : 9 acetone : petroleum ether brought down a light brown zone. Subsequent elution with 1 : 1 acetone : petroleum ether brought down a brown zone and final elution of the column with acetone brought down a small quantity of brown residue. Each eluate was collected separately and the solvent allowed to evaporate at room temperature, leaving four fractions of chlordane. The first fraction, CI, contained the bulk of the material and was a yellow viscous liquid. The second, smaller fraction, CII, was a light brown viscous liquid. The third fraction, CIII, was dark brown, almost solid and smaller again in quantity. The fourth fraction was too small in quantity to examine separately and was probably the same as the third fraction. The three fractions were tested separately for their cytological effects on onion root-tips.

An attempt to separate toxaphene by the same method was unsuccessful, suggesting that it is a single compound.

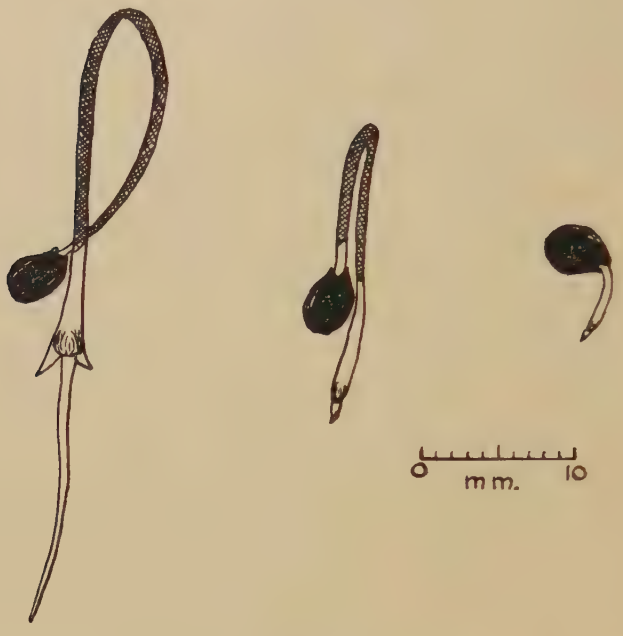

FIG. 1.

Onion seedlings ten days after germination in Petri dishes. Left—Control. Centre—Germinated in contact with 0·15 gm. chlordane on gypsum and removed 24 hours after germination. Right—Germinated in contact with 0·015 gm. fraction CIII on gypsum and removed 24 hours after germination.

PETRI DISH EXPERIMENTS.

Seeds of the onion, *Allium cepa*, were germinated in Petri dishes under the same conditions as those described in a previous paper (Scholes, 1953). They were directly in contact with the dose of insecticide under investigation. The temperature, recorded by a maximum and minimum thermometer, varied daily between 58° F. and 80° F. for controls and treated seedlings. Fixations were carried out at similar times each morning to minimize the effects of this temperature variation in determining the mitotic index. The varieties Ailsa Craig and A.1 were used, the failure of the 1952 seed crop of Ailsa Craig necessitating a change in variety. It has been found in the course of these experiments that onion seed does not store well and it is unwise to use seed which is more than one year old for cytological investigations of root-tips. The percentage germination decreases and abnormalities such as broken chromatids in anaphase occur in untreated roots ; this confirms observations by Nichols (1941) and Harrison and McLeish (1954).

Root-tips were fixed in acetic-alcohol 48 hours after germination. In the control experiments the roots attained a length of 1 cm. in this time and this was taken as the standard of normal growth. Feulgen root-squashes were prepared.

Toxaphene, chlordane fraction CII and *gamma* chlordane had no effect on germination or growth rate of onion seedlings under the conditions of these experiments. Chlordane, fraction CI, or technical or purified heptachlor had no effect on germination, but roots grown in contact with each of these compounds attained a

length of only 6 mm. in 48 hours. Fraction CIII retarded germination by 2–3 days and entirely inhibited growth.

Fig. 1 shows a seedling which was removed from a dose of 0·15 gm. chlordane on gypsum 24 hours after germination. Although the bulb began to develop, the tap root decayed prematurely without development of adventitious roots. In the case of fraction CIII the seedlings did not recover when removed from the dust, but remained at the stage shown in Fig. 1. It was necessary to reduce the dose to 0·002 gm. dust to grow roots 6 mm. long in 2–3 days after germination.

MITOTIC INDEX AND MITOTIC FORMULA IN PETRI DISH EXPERIMENTS.

The mitotic index and mitotic formula were determined for six control roots and for six roots in each experimental group, by counting 2,500–3,500 cells in each root.

(*a*) *Chlordane.*

A comparison of the mitotic index and mitotic formula for controls and roots treated with chlordane or fractions of chlordane is shown in Tables II and III. Two significant differences are quoted in each column because the variation between replicates was smaller for controls than for treated roots. Two treatments differ significantly if the difference between their means is greater than the first significant difference given. A treatment differs significantly from the controls if the difference between its mean and the control mean is greater than the second significant difference given. The standard error of the control mean has been quoted to show the accuracy of the determination of this mean in roots grown at the variable temperature given above.

TABLE II.

Comparison of mitotic index and mitotic formula for controls and roots treated with chlordane and fractions of chlordane.

Treatment. Dose in gm.	Mean % dividing cells	Mean % prophases	Mean % metaphases	Mean % anaphases	Mean % telophases
Controls	14·3	43·1	10·4	3·4	43·1
Standard error of control mean	0·19	0·26	0·33	0·22	0·38
0·015 chlordane on gypsum	10·8	53·7	13·3	3·5	29·4
0·15 chlordane on gypsum	9·3	56·6	11·2	3·3	28·9
0·15 fraction CI on gypsum	12·3	50·8	12·1	4·8	32·4
0·15 fraction CII on gypsum	16·8	47·2	8·9	2·3	41·5
0·002 fraction CIII on gypsum	7·8	53·9	11·1	1·8	32·9
Significant difference (P=0·05)	2·59	11·43	2·93	1·34	8·62
Significant difference from controls (P=0·05) ..	1·86	7·94	2·14	1·04	6·08

Table II shows that the mitotic index is significantly lowered by the two doses of chlordane, but the effect is independent of the dose. Chlordane is very sparingly soluble in water ; increasing the dose probably does not increase the concentration

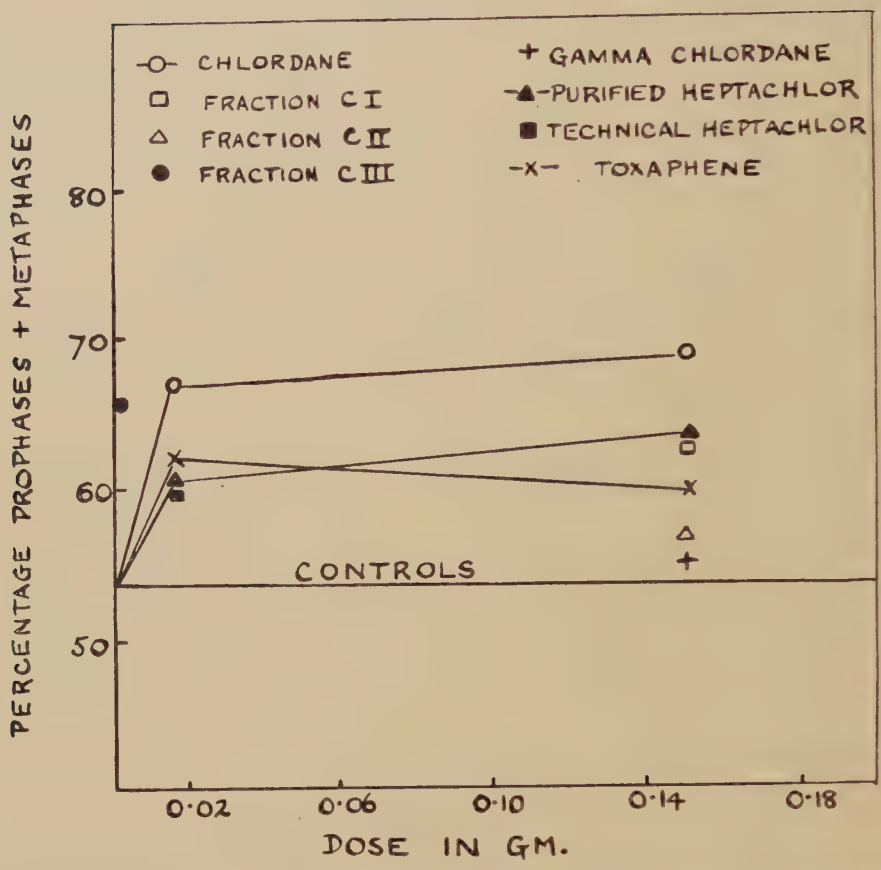

Fig. 2.

Graph showing the frequencies of cells at prophase and metaphase after treatment with chlordane, fractions CI, CII and CIII, *gamma* chlordane, purified or technical heptachlor or with toxaphene.

in the cell. There is a significant increase in the number of prophases with a corresponding decrease in the number of telophases seen. Many of the cells were in pro-metaphase and for this reason the change in frequency of prophases+metaphases after contact with chlordane and the three fractions of chlordane has been shown in Fig. 2. The point for fraction CIII has been plotted arbitrarily because it refers to a dose of 0·002 gm. A comparison of the effects of the three fractions shows that a significant reduction in the mitotic index is caused by fractions CI and CIII, the latter showing the greater effect. The change in frequency of prophases is mainly caused by fraction CIII but the decrease in frequency of telophases is a combined effect of fractions CI and CIII. Fraction CII does cause an increase in the mitotic index which is just significant, but it is the only fraction which does not change the mitotic formula and shows significant differences from the other treatments.

(*b*) *Heptachlor and gamma chlordane.*

Table III shows that heptachlor and *gamma* chlordane have no effect on the mitotic index, but, as shown in Fig. 2, heptachlor causes a change in frequency of

prophases+metaphases which is less than that caused by chlordane but comparable with fraction CI. *Gamma* chlordane has no such effect and compares with fraction CII.

TABLE III.

Comparison of mitotic index and mitotic formula for controls and roots treated with technical heptachlor, purified heptachlor and gamma chlordane.

Treatment. Dose in gm.	Mean % dividing cells	Mean % prophases	Mean % metaphases	Mean % anaphases	Mean % telophases
Controls	15·3	46·4	9·5	2·1	41·9
Standard error of control mean	0·27	0·87	0·41	0·26	0·84
0·015 technical heptachlor on gypsum ..	16·5	53·5	6·8	1·9	37·7
0·015 purified heptachlor on gypsum	15·6	52·8	8·6	1·9	36·7
0·15 purified heptachlor on gypsum	15·9	55·4	8·3	2·0	34·4
0·15 gamma chlordane on gypsum	16·2	48·1	6·6	1·6	43·7
Significant difference (P=0·05)	3·48	6·65	2·34	1·02	6·20
Significant difference from controls (P=0·05) ..	2·05	4·23	1·83	0·78	3·91

(*c*) *Toxaphene.*

Table IV shows that toxaphene has no effect on the mitotic index, but there is a significant increase in the number of metaphases with a corresponding decrease in the number of telophases, which is independent of the dose.

TABLE IV.

Comparison of mitotic index and mitotic formula for controls and roots treated with toxaphene.

Treatment. Dose in gm.	Mean % dividing cells	Mean % prophases	Mean % metaphases	Mean % anaphases	Mean % telophases
Controls	14·3	43·1	10·4	3·4	43·1
Standard error of control mean	0·19	0·26	0·33	0·22	0·38
0·015 toxaphene on gypsum	16·8	46·3	15·2	3·3	35·1
0·15 toxaphene on gypsum	13·2	44·7	14·6	3·6	37·5
Significant difference (P=0·05)	6·02	4·82	3·28	1·10	4·80
Significant difference from controls (P=0·05) ..	4·09	3·29	2·30	0·86	3·24

CYTOLOGICAL EFFECTS OF CHLORDANE.

The lowering of the mitotic index was caused by a lethal effect on the resting cells ; some of the resting nuclei were contracted to small strongly-stained lumps and some were directly fragmented into a number of small pieces. There was a

decrease of the order of 20 per cent. in the number of cells in early prophase, but an increase in the number of cells in pro-metaphase. The chromosomes appear as a loose tangle of long threads (Plate I, Fig. 3a) which are delayed in passing into metaphase by a disturbance in the time sequence of events in the dividing cell. The majority of metaphases had the diploid number of chromosomes arranged on a spindle, but occasional tetraploid metaphases, scattered anaphases or multipolar telophases were found in each root, suggesting that the formation of the spindle may be delayed or prevented. Other cytological effects, which were less pronounced, were those which Levan (1949) described as characteristic of the lethal and sub-narcotic zones, the narcotic zone being specially characterized by the occurrence of the c-mitotic reaction. These effects included, in the sub-narcotic zone, pseudo-chiasmata, chromosome erosion leading to many chromosome constrictions in one cell (Plate I, Fig. 3c) and fragmentations and, in the lethal zone, liquefaction of the matrix revealing the spiral structure of the chromosomes in late prophase. La Cour and Rutishauser (1953) have shown that the pseudo-chiasmata are, in fact, sub-chromatid breaks which may give homologous intercalary point effects or may involve non-homologous loci through breakage and re-union in coiled and overlapping chromatids at prophase. In approximately 20 per cent. of the telophases counted, the spiral structure of the chromatids was clearly visible (Plate I, Fig. 3b). These cells had completed anaphase, but no nuclear membrane was formed and they were breaking down. The question arises whether this is an effect on the dividing cell which is manifest in early telophase or an effect on telophase itself.

In order to investigate this point, the length of the onion root when cells first enter mitosis was determined. It was found that roots 2–3 mm. long have many cells entering prophase, but few later stages. Actual counts of telophases in three roots were 11, 17 and 19. By growing seedlings to a length of 2–3 mm., then growing them in contact with the chlordane dust for 24 hours and fixing the root-tips, it was possible to examine cells which must have reached telophase following the treatment with the dust. Previous experiments had shown that 24 hours was long enough for penetration. The numbers of normal telophases and those showing spiralized chromatids, were counted in five roots. The number of normal telophases varied between 31 and 75 and those showing spiralized chromatids between 17 and 24. The latter number is closely comparable with the number of telophases found in untreated roots of the same initial length ; it seems a reasonable inference that the effect is on early telophase itself.

Cytological effects of fractions of chlordane.

These experiments have shown that each fraction of chlordane is responsible for a different cytological effect. Fraction CII had no effect under the conditions of the experiments. Fraction CI caused fragmentation of chromosomes observable in metaphase and anaphase ; in three of the roots examined, approximately 25 per cent. of the metaphases had one or more broken chromosomes, with no evidence of restitution. Some of the cells were shattered into numerous fragments, others were forming multipolar telophases around the fragments. The lowering of the mitotic index and number of telophases is due to the loss of cells by fragmentation. This fraction also caused the delay in pro-metaphase. Although the increased number shown in Table II is not significant, it is undoubtedly reduced by the larger number of shattered cells which could not be recorded.

PLATE I

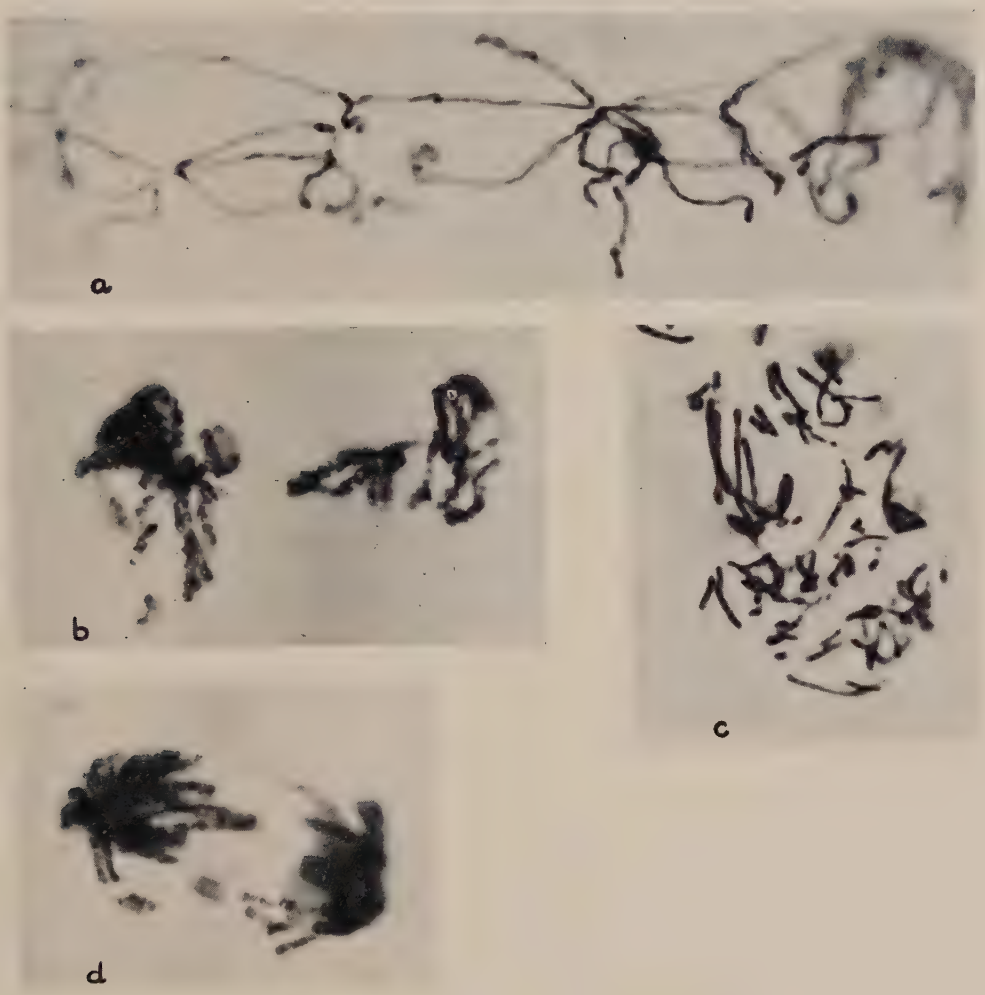

FIG. 3.

Photomicrographs of treated root-tips of *Allium cepa* (×1,260).

PETRI DISH MATERIAL: 0·015 gm. toxaphene on gypsum: (*a*) Pro-metaphase. (*b*) Late telophase showing spiralized chromatids. 0·075 gm. chlordane on gypsum: (*c*) Pro-metaphase showing numerous fragments. 0·15 gm. chlordane on gypsum: (*d*) Free fragments in anaphase 72 hours after removal from insecticide.

[*face p.* 18

Fraction CIII caused the lethal effects. Examination of roots grown with 0·015 gm. of this fraction on gypsum showed that mitosis had been completely inhibited, the resting nuclei did not appear vital, and in some roots the nucleus was reduced to a number of Feulgen-positive droplets. This fraction is a small one and the dose was greatly in excess of the dose given by the same weight of chlordane. By reducing the dose to 0·002 gm. of the dust it was possible to grow roots with a mitotic index which was not significantly different from the higher dose of chlordane. It is clear that the lowering of the mitotic index is mainly due to the lethal effect of fraction CIII. The significant increase in the number of prophases was due to the accumulation of a large number of early stages after the initial delay in entering mitosis. As shown in Fig. 2, the increases in the number of pro-metaphases caused by fraction CI and toxaphene were closely comparable. Both these compounds caused a delay in pro-metaphase but the greater increase caused by chlordane was due to the combined effects of fractions CI and CIII. The lethal effect on telophase was also caused by fraction CIII ; the decrease in the number of telophases caused by chlordane being a result of this lethal effect and fragmentation caused by fraction CI.

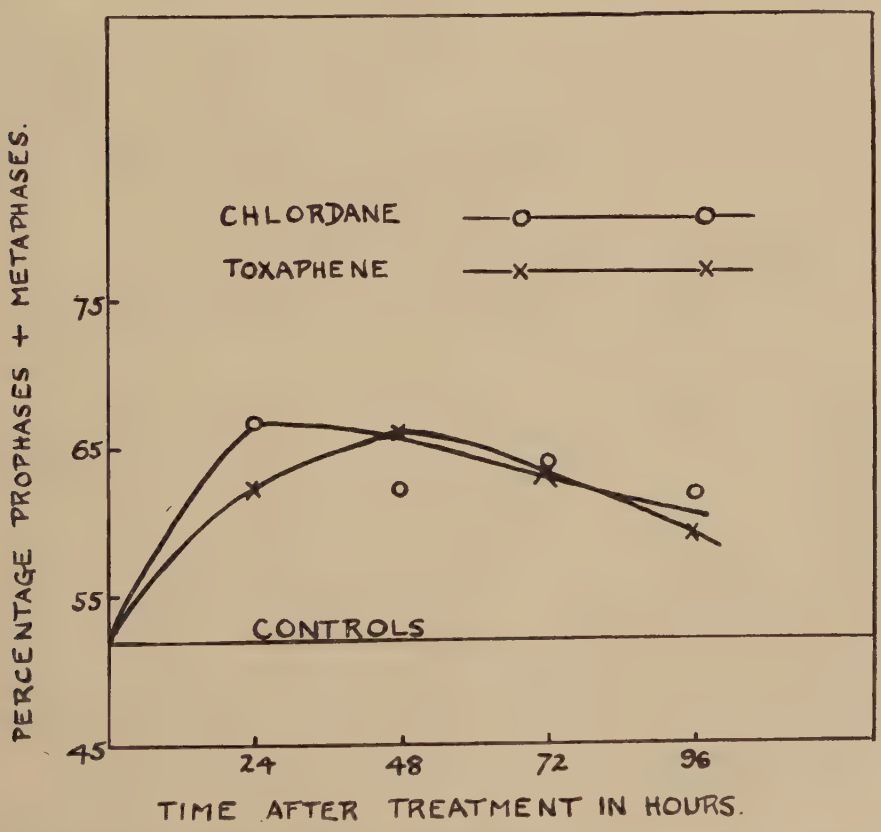

FIG. 4.

Graph showing the frequencies of cells at prophase and metaphase at various intervals after removal from chlordane and toxaphene.

Cytological effects of heptachlor and gamma chlordane.

The effects of technical and purified heptachlor were comparable with that described for fraction CI. *Gamma* chlordane was without effect and was comparable with fraction CII. Technical heptachlor also caused the telophase effect described for fraction CIII, but to a lesser degree ; it is clearly more potent than the purified material. The higher dose of the purified heptachlor caused some resting cells to appear as strongly stained lumps, apparently as a result of clumping in the previous late telophase.

Cytological effects of toxaphene.

Toxaphene differed from chlordane in its milder lethal effect. Although its effect on telophase was comparable with that of fraction CIII, it had no effect on resting cells. In causing a delay in pro-metaphase and fragmentation of chromosomes, its effects were essentially similar to those of fraction CI and do not need further description.

Effect of removal from chlordane and toxaphene.

Seeds were germinated in contact with a dose of 0·15 gm. of the dust under investigation. Seedlings were removed 24 hours after germination, washed, put in a clean dish on clean filter paper and kept moist with distilled water. Root-tips were fixed at 24-hour intervals after removal. Two roots were examined in each group and the results are shown in Table V and Fig. 4 ; the points were plotted by taking an average value from the two roots in each group.

Table V.

Mitotic index and mitotic formula for roots examined 24, 48, 72 and 96 hours after removal from chlordane and toxaphene.

Time in hours between removal from insecticide and fixation	0·15 gm. chlordane on gypsum			0·15 gm. toxaphene on gypsum		
	% dividing cells	% prophases + metaphases	% anaphases + telophases	% dividing cells	% prophases + metaphases	% anaphases + telophases
Controls	14·3	53·5	46·5			
24	10·6	67·6	32·3	13·4	61·1	39·1
24	13·6	67·5	32·6	14·2	63·9	36·2
48	9·4	60·3	39·7	13·6	67·6	32·4
48	4·7	65·1	35·3	11·2	65·0	35·2
72	11·6	64·3	35·7	12·2	68·4	30·8
72	13·3	65·0	35·0	14·8	58·7	41·3
96	13·3	66·0	33·9	16·2	58·6	41·3
96	13·2	59·5	40·6	16·9	59·2	40·7

(*a*) *Recovery from chlordane.*

Table V shows that the number of cells in division falls to a minimum 48 hours after removal and returns to normal in roots examined at later intervals. Moribund resting cells, appearing as strongly stained lumps, were seen in roots examined at

24 and 48 hours after removal, but this effect was entirely absent at later intervals. As shown in Fig. 4, the increase in the combined numbers of prophases and metaphases reaches a maximum 24 hours after removal and then tends towards normal. The immediate increase is partly due to a delay in pro-metaphase and partly to an increase in the number of cells coming into prophase. At later intervals it is due only to an increase in the number of cells coming into prophase as the number of affected resting cells decreases. The breakdown of cells which failed to de-spiralize in telophase was evident in all roots examined. This effect was still apparent in a few cells 96 hours after removal from the insecticide ; it decreases with time, but is the most persistent of the observed effects of chlordane.

Anaphase bridges were rarely seen in roots examined immediately after contact with chlordane, but they occurred frequently in roots recovering from contact. In roots examined 24 and 48 hours after removal, approximately 40 per cent. of the anaphases had bridges, the number increased to approximately 65 per cent. at 72 hours and fell again to 40 per cent. at 96 hours. These bridges were usually formed by more than one chromosome ; they were sticky bridges, and sharply distinct from chromatid bridges. Free fragments were observed in metaphase and anaphase (Plate I, Fig. 3d) up to 72 hours after removal but not at 96 hours.

(*b*) *Recovery from toxaphene.*

As shown in Fig. 4, the percentage of prophases+metaphases reaches a maximum 48 hours after removal. It is entirely due to a continued delay in pro-metaphase. Toxaphene differs from chlordane in this effect, but shows a similar effect on telophase up to 96 hours after removal. It is evident that the breakdown of cells in telophase can be caused by an extremely low concentration of either of these compounds. The number of anaphase bridges seen was slightly less than with chlordane, attaining a maximum of approximately 55 per cent. at 72 hours but falling to zero at 96 hours. Fragments in metaphase and anaphase also appear up to 72 hours.

POT EXPERIMENTS.

The soil used in these experiments was garden loam, partially sterilized by steaming at 180° F. and watered with rain water. The seeds were covered with $\frac{1}{8}$ in. of soil, the dose of insecticide spread on the surface layer and mixed with it to simulate broadcasting in the field. The doses used are shown in Table I. The temperature during these experiments varied between 54° F. and 80° F. Seventy-five seeds were sown in each group. Seedlings were raised eleven days after sowing and eight root-tips from each group, taken from roots varying in length from 0·5 to 5 cm., were fixed and examined cytologically.

Toxaphene had no effect on the time of emergence of the cotyledon or on the growth rate of the roots. Chlordane retarded the growth of the seedlings. The lower dose reduced the number of cotyledons emerging at eleven days after sowing by 20 per cent. and the higher dose caused a 45 per cent. reduction. The roots appeared normal, but there was a larger proportion of short roots with both doses.

Cytological effects.

Each root was examined for the appearance of pro-metaphases, affected telophases and fragments in metaphase and anaphase. Toxaphene, applied at the rate of 20 lb. per acre, had little effect. Only one root, 5 cm. in length, showed the typical

effects described for the higher dose. When applied at the rate of 200 lb. per acre, five of the roots examined, varying in length from 0·5 to 4 cm., were affected. The number of pro-metaphases seen was approximately 50 per cent. and the number of affected telophases was approximately 25 per cent. of those found in Petri dish material with a dose of 20 lb. per acre. Approximately 30 per cent. of the metaphases examined had broken chromosomes, many of them were badly shattered, and approximately 80 per cent. of the anaphases showed excluded fragments.

Chlordane had a greater effect than toxaphene. When applied at the rate of 20 lb. per acre, five of the roots examined, varying in length from 1 to 2·5 cm., were affected. The number of pro-metaphases seen was approximately 50 per cent. and the number of affected telophases was approximately 60 per cent. of those found in Petri dish material with an equivalent dose. About 35 per cent. of the metaphases had one or more broken chromosomes and 75 per cent. of the anaphases had excluded fragments. When applied at the rate of 200 lb. per acre, all the roots examined were affected in a similar way with a greater number of affected telophases.

DISCUSSION.

These experiments show that chlordane and toxaphene act as weak narcotics in causing delay in the appearance of the spindle and other effects attributed by Levan (1949) to the sub-narcotic and lethal zones. They also cause the loss of some cells in root meristems, but there is little direct evidence of factors which would cause genetical changes if the ability of a chemical compound to induce breaks in mitotic chromosomes is taken as a measure of its true mutagenic action. Whilst D'Amato (1952) upholds this definition of a mutagenic compound, he has discussed the objections of others to it. Levan (1951) considered that the important question whether substances inducing gene mutations had always the ability to break the chromosome thread was still not settled, and stated that a substance found to be mutagenic in a genetical test might fail to induce structural chromosome changes in a cytological test and *vice versa*. Danielli (1952) drew attention to the possibility of the majority of chemical substances being mutagenic in appropriate circumstances, since immeasurably small traces of their reaction products in a cell may suffice for the production of mutations. Whilst this question remains unsettled, it is important, when using either chlordane or toxaphene as insecticides, to realize that they are not without effect on the dividing cell.

The Petri dish experiments show the effects of the maximal doses with which roots are likely to come into contact in the soil. They are able to recover from the effects of contact with either compound, although chlordane reduces the growth rate by its lethal effect on resting cells. The pot experiments show that heavy doses or local concentrations of each compound will cause cytological effects in a proportion of the seedlings which is too large to be ignored. Chlordane had deleterious effects when applied at the low rate of 2 lb. actual compound per acre.

It is clear from the cytological tests with the fractions from chlordane that fraction CIII has the lethal effect, and that fraction CI, which contains most of the substance, is responsible for effects on the dividing cell. These effects are also caused by technical and purified heptachlor. The melting point of the purified heptachlor (91°–93° C.) agrees with that given by March (1952) for his fraction II and this fraction proved to be the most toxic to insects. The melting point of *gamma* chlor-

dane (102°–104° C.) is nearest to March's fraction IV (104·5°–106° C.), and this fraction was least toxic to insects. Fractions CI and CII obtained by chromatographic adsorption in these experiments compare with the purified heptachlor and *gamma* chlordane respectively in their cytological effects. It seems clear that the insecticidal properties of chlordane are due to fraction CI and that the phytotoxic effects are mainly caused by fraction CIII. The removal of fraction CIII would greatly reduce its phytotoxicity without reducing its insecticidal properties. Fraction CII has very little effect on either the plant or the insect.

Kearns *et al.* (1945) found that chlordane was more toxic than DDT and compared favourably, in toxicity to certain insects, with the pure *gamma* isomer of BHC. If the phytotoxic effect of chlordane could be reduced by removing the third fraction on a commercial scale, there may be circumstances in which it would be preferable to use it in place of BHC, since it does not cause polyploidy. Toxaphene also has this advantage.

SUMMARY.

1. Onion seeds have been germinated in contact with 10 per cent. mixtures of technical toxaphene, chlordane, fractions of chlordane, technical and purified heptachlor or *gamma* chlordane, on gypsum.

2. The doses used were equivalent to 20 and 200 lb. per acre of the dusts.

3. Technical chlordane was separated into fractions CI, CII and CIII, by the chromatographic adsorption method.

4. Toxaphene, chlordane, fractions CI and CII, heptachlor and *gamma* chlordane had no effect on germination, but fraction CIII retarded it. Growth rate was retarded by chlordane, fractions CI and CIII, and by technical and purified heptachlor.

5. The frequency of nuclear divisions was unaffected by toxaphene, fraction CII, heptachlor and *gamma* chlordane, but reduced by chlordane and by fractions CI and CIII.

6. Toxaphene and chlordane delayed cells in pro-metaphase, and prevented nuclear reconstruction in telophase. In addition, chlordane had a lethal effect on resting cells.

7. Fraction CI caused delay in pro-metaphase and fragmentation of chromosomes and fraction CIII caused the lethal effect on resting cells and telophase.

8. The cytological effects of technical and purified heptachlor were comparable with that described for toxaphene and fraction CI. *Gamma* chlordane had no effect.

9. Roots recover from contact with toxaphene and chlordane, but the effect on telophase is manifest for a period of at least 4 days after removal from the insecticides.

10. In pot experiments a low dose of toxaphene had little effect, but a low dose of chlordane and high doses of both compounds affected a large proportion of the roots examined.

ACKNOWLEDGMENTS.

The author is grateful to Dr. K. S. Dodds, Director of the John Innes Horticultural Institution, for his helpful advice whilst carrying out this work and for reading the manuscript. She also wishes to acknowledge the constant interest taken by Dr. A. B. Beakbane and Dr. A. H. M. Kirby of East Malling Research Station and the

help of Dr. Kirby in supplying samples of the insecticides used. She is grateful to Mr. G. E. Marks of the Potato Genetics Station, Cambridge, for preparing the photographs and to the Agricultural Research Council for their generous support.

REFERENCES.

Brown, A. W. A. (1951). Insect control with chemicals. John Wiley & Sons, New York.

Casida, J. E., and *Allen, T. C.* (1952). Absorption and translocation of insecticides by plants. Agr. Chem., **7,** 41.

Cullinan, F. P. (1949). Some new insecticides—their effect on plants and soil. J. econ. Ent., **42,** 347.

D'Amato, F. (1952). The cytological study of chemical mutagens. Genetica Iberica IV, 3.

Danielli, J. F. (1952). Separate nuclear and cytoplasmic actions of drugs. Nature, **170,** 1042.

Harrison, B. J., and *McLeish, J.* (1954). Abnormalities of stored seed. Nature, **173,** 593.

Kearns, C. W., Ingle, L., and *Metcalf, R. L.* (1945). A new chlorinated hydrocarbon insecticide. J. econ. Ent., **38,** 661.

La Cour, L. F., and *Rutishauser, A.* (1953). Chromosome breakage experiments with endosperm : Sub-chromatid breakage. Nature, **172,** 501.

Levan, A. (1949). The influence on chromosomes and mitosis of chemicals, as studied by the *Allium* test. Hereditas, Suppl. Vol. 325.

——— (1951). Chemically induced chromosome reaction in *Allium cepa* and *Vicia faba*. Sym. Quan. Biol., XVI, 233.

March, R. B. (1952). The resolution and chemical and biological characterization of some constituents of technical chlordane. J. econ. Ent., **45,** 452.

Nichols, C. (1941). Spontaneous chromosome aberrations in *Allium*. Genetics, **26,** 89.

Morrison, H. E., Crowell, H. H., Crumb, S. E., Jr. and *Lauderdale, R. W.* (1948). The effects of certain new soil insecticides on plants. J. econ. Ent., **41,** 374.

Scholes, M. E. (1953). The effect of hexachloro*cyclo*hexane on mitosis in roots of the onion (*Allium cepa*) and strawberry (*Fragaria vesca*). J. hort. Sci., **28,** 49.

Turner, N., and *Woodruff, N.* (1948). Chlorinated insecticides for control of the potato flea beetle. J. econ. Ent., **41,** 328.

(*Received* 12/5/54.)

APPLE ROOTSTOCK STUDIES: MALLING-MERTON ROOTSTOCKS

By A. P. PRESTON
East Malling Research Station

FRUITGROWERS in many Commonwealth countries and in parts of the U.S.A. are particularly interested in rootstocks resistant to the Woolly Aphid (*Eriosoma lanigerum* Hausm.) because the resistant Northern Spy is unsatisfactory both in the nursery and the field. In England also, Woolly Aphid infestations in the stoolbed have proved difficult to control, the original rootstocks selected and classified at East Malling being all susceptible. Resistant rootstocks having pomological qualities as good as or better than existing ones would thus be useful to nurserymen and to growers both in England and abroad.

A breeding project undertaken jointly in 1928 by the John Innes Horticultural Institution (then at Merton) and East Malling Research Station produced new rootstock clones resistant to Woolly Aphid. These are now called the Malling–Merton rootstocks (Preston, 1953a). This paper summarizes the results of twenty-five years' breeding and selection and describes the range in vigour and fruitfulness of trees on these rootstocks that has been achieved.

HISTORICAL.

Crane at Merton and Tydeman at East Malling started breeding rootstocks in 1922; their efforts were greatly intensified in 1928, with the object of obtaining new rootstocks covering a wide range of vigour and possessing good propagation qualities in addition to resistance to the Woolly Aphid (Hatton *et al.*, 1937). Some 3,758 seedlings raised at Merton and East Malling, mainly from crosses between Northern Spy and rootstocks in the Malling selections, were tested in the insectary for resistance; rootstocks which passed this test were propagated vegetatively by stooling and their propagation qualities were recorded (Crane, Greenslade, Massee and Tydeman, 1936). Extensive studies have been made since 1936 on their propagation qualities and suitability to a wide range of scion varieties (Garner, 1953).

The rootstocks were retested in the insectary during the period 1949 to 1951 (Massee, unpublished data); fifteen which were again found resistant have been numbered Malling–Merton 101 to 115 (MM.101 to MM.115) and descriptions published (Tydeman, 1953). One new rootstock appears to be of promise for both vigour and early cropping but is not so highly resistant. It has not, therefore, been numbered among the Malling–Merton rootstocks but will be known as Malling XXV (M.XXV). The origin and parentage of the new rootstocks, together with other details, are given in Table I.

MATERIALS AND METHODS.

The correlation found by Beakbane and Thompson (1939) between root structure of a rootstock and the vigour of a scion worked upon it was used to classify the new rootstocks in provisional vigour groups (Beakbane, Thompson and Tydeman, 1941). Representative rootstocks from each group were selected for extensive field trial.

TABLE I.

Parentage and origin of the new rootstocks, their ease of propagation when stooled and their suckering propensity in the field compared with some rootstocks in the Malling clones, Northern Spy and Ivory's Double Vigour.

Root-stock	Parentage ♀	Parentage ♂	Origin*	Propaga-tion quality†	Suckering data for Trials A, B, C and D combined, 1948–51			
					Number of trees suckering (out of 24)	Recurrence. Mean number of years recorded, maximum 4 years	Mean number of suckers per tree for trees suckering over a 4-year period	Vigour of suckers 1=weak 3=strong
MM.101	Spy	M.I	J.I.	A	3	1·0	2·0	1·3
MM.102	Spy	M.I	E.M.	B	1	1·0	2·0	1·0
MM.103	Spy	Ben Davis	E.M.	C	2	1·0	1·0	2·0
MM.104	M.II	Spy	E.M.	A	0	0	0	0
MM.105	M.II	Spy	J.I.	A	2	1·0	1·5	3·0
MM.106	Spy	M.I	E.M.	B	0	0	0	0
MM.107	Spy	M.XV	E.M.	B	2	1·0	1·5	2·0
MM.108	Spy	M.XV	E.M.	B	0	0	0	0
MM.109	M.II	Spy	J.I.	B	0	0	0	0
MM.110	Spy	M.I	E.M.	B	0	0	0	0
MM.111	Spy	Merton 793	J.I.	B	1	2·0	1·0	1·0
MM.112	Spy	Winter Majetin	E.M.	B	0	0	0	0
MM.113	Spy	M.XII	E.M.	D	0	0	0	0
MM.114	Spy	M.XII	E.M.	D	1	1·0	1·0	3·0
MM.115	Spy	M.II	E.M.	B	0	0	0	0
M.XXV	Spy	M.II	E.M.	C	1	1·0	3·0	1·0
M.XVI				B	0	0	0	0
M.II				B	0	0	0	0
M.I				B	0	0	0	0
M.VII				B	5	1·6	2·4	2·0
M.IV				B	4·5‡	1·3	1·2	1·3
M.IX				C	4	1·2	2·1	2·3
Ivory's Double Vigour				D	0	0	0	0
Northern Spy				D	0	0	0	0

* J.I.=John Innes Horticultural Institution ; E.M.=East Malling Research Station.
† A=excellent, B=good, C=fair, D=poor ; data supplied by Mr. R. J. Garner.
‡ See text.

Three scion varieties were chosen for the trials, Cox's Orange Pippin and Jonathan, because of their world-wide importance, and Ellison's Orange, a variety which has some reputation for bearing crops of fruit in years when other varieties have suffered damage from late spring frosts.

Four main trials were planted. Trials A and C included rootstocks which were expected to fall within the intermediate range of vigour, and Trials B and D those expected to make vigorous or very vigorous trees. Trials A and B were planted on the Malling soil series, of sandy loam texture, and Trials C and D on a gravelly phase

of the Bearsted soil series, of sandy texture. Details of the soils of the two sites have been published (Preston and Stanton, 1947 ; Furneaux, 1954). Each trial contained 12 trees on each rootstock distributed in four randomized blocks. Trees on the original Malling selections were included as controls in each trial ; in addition, the Woolly Aphid-resistant rootstocks Northern Spy (abbreviated to Spy) and Ivory's Double Vigour (I.D.V.), obtained from New Zealand, were included. Planting distances were related to the soil and to the provisional vigour group ; in Trial A they were 18 × 15 feet, in Trial B 18 × 20 feet, in Trial C 15 feet square and in Trial D 18 feet square.

The rootstocks used as standards for comparison in Trials A and C were M.IX (dwarfing), M.IV and M.VII (intermediate), and Spy ; in Trials B and D they were M.IV (intermediate), M.I and M.II (vigorous), M.XVI and I.D.V. (very vigorous). The best comparison can be made within any one trial, but trees on M.IV, included in both Trials A and B (Malling soil series) and C and D (Bearsted soil series), form a link between the two trials within each soil series. The suckering data have been averaged for trees on M.IV in Table I ; the actual numbers of trees that had suckered on this rootstock in each trial (maximum 12) were as follows : Trial A—3 trees, B—2 trees, C—nil, and D—4 trees.

Owing to a restriction on randomization in the design of Trial B, to allow for future tree-thinning (Pearce and Hoblyn, 1948), a more accurate comparison is made between rootstocks within certain groups, as follows :

Group 1=MM.107, MM.112, MM.114 and M.XXV
Group 2=MM.109, MM.111 and I.D.V.
Group 3=MM.108, MM.110 and M.II
Group 4=MM.113, MM.115, M.I, M.IV and M.XVI

The minimum difference required for significance occurs within a group while the maximum difference occurs between trees on rootstocks in Groups 1 and 4. Both differences are shown in the Tables.

In all trials one-year-old trees were planted during the winter of 1945–46 and all grew well in their first summer, a wet one. Two of the most serious summer droughts recorded at East Malling occurred in 1947 and 1949. No drought effects were noted in the trials on Malling soil series, but severe damage was recorded in those on Bearsted soil series in both years and some trees on M.I and Spy died.

All trees have been winter pruned by the Regulated method in order to obtain early data on relative cropping. This has brought the trees into early and heavy bearing even on very vigorous rootstocks. No fruit thinning has been practised. Apart from pruning, no attempt has been made to give uniform cultural treatment to the trials on the two soils, the aim being to apply the cultural treatment best suited to the needs of the soil. Thus, all four trials have been clean cultivated since they were planted, and autumn weeds allowed to grow, but the two trials on the Bearsted series have had two broadcast applications of farmyard manure and the trees were mulched with dung during the drought summers of 1947 and 1949.

Results.

Vigour.

Although three widely differing scion varieties were included in these trials, during the first seven years now under review all three responded very nearly alike

to the various rootstocks on which they were worked. In the following Tables and discussion of results the three varieties are therefore grouped together.

During the first three years shoot growth was measured. On the Malling soil series trees on MM.104 showed greater initial vigour than did those on M.IV and trees on MM.106 less than did those on M.VII. Trees on rootstocks MM.109–MM.112 inclusive made more shoot growth than did those on M.II, trees on MM.112 being the nearest in vigour to those on M.II. Trees on M.XXV were more vigorous than were those on M.II and were very similar to those on M.XVI and MM.115. On the Bearsted soil series trees on M.VII and MM.104 were outstanding for initial vigour and, as on the Malling soil, trees on MM.112 were similar to those on M.II, and trees on MM.109 and MM.110 were more vigorous.

TABLE II.

Mean trunk girth (cm.) of three scion varieties, 1951.

Rootstock	Malling series	Bearsted series
	Trial A	Trial C
MM.101	17·2	13·7
MM.102	17·0	10·2
MM.103	22·4	15·8
MM.104	23·5	14·7
MM.105	19·8	15·4
MM.106	15·9	11·2
M.IV	19·0	13·9
M.VII	17·9	13·5
M.IX	9·7	7·3
Spy	17·0	11·4
Sig. ratio (P=0·05) ..	1·14	1·11
	Trial B	Trial D
MM.107	16·1	14·3
MM.108	17·5	11·6
MM.109	19·7	15·0
MM.110	17·8	15·3
MM.111	18·3	13·1
MM.112	17·0	13·1
MM.113	22·0	16·2
MM.114	21·3	15·2
MM.115	21·6	15·5
I.D.V.	21·6	15·6
M.I	16·4	12·0
M.II	16·6	11·7
M.IV	20·3	13·7
M.XVI	20·3	16·3
M.XXV	19·8	13·5
Sig. ratio (P=0·05)		
Maximum ..	1·15	
Minimum ..	1·12	1·14

Shoot growth records were later replaced by the weight of winter prunings as a vigour measurement ; good agreement was found between this growth record and trunk girth (Table II).

Trunk girth, twelve inches above the union, was measured annually. The statistical analyses were done on the logarithms of the girths. In Table II these are

transformed back to the actual mean trunk girths, when the significant differences become ratios. For example, in Trial A, the ratio of the girth on MM.106 to that on M.VII is only 1·13 and is not significant, whereas in Trial C this ratio is 1·20 and is significant ($P<0·05$). Trees on Bearsted soil series, as might be expected, were much smaller than were those on the Malling soil.

It is clear that the new rootstocks cover a useful range of vigour but none of them are much more dwarfing than M.VII. Both Crane and Tydeman (*loc. cit.*) reported a high degree of incompatibility in matings between M.IX and Spy and the few seedlings produced were found susceptible to the Woolly Aphid ; this undoubtedly reduced the chances of a very dwarfing rootstock reaching the field trials.

Anchorage.

All trees have been staked since they were planted, but at seven years old they were untied and their anchorage was measured by estimating their resistance to rocking by hand in three directions. The tests were carried out by two recorders, working independently, and their records agreed well. The mean category figures are shown in Table III, the higher values indicating better anchorage.

TABLE III.

Mean anchorage category of three scion varieties, 1951.

Rootstock	Malling series	Bearsted series
	Trial A	Trial C
MM.101	3·7	3·8
MM.102	3·1	2·6
MM.103	4·6	4·2
MM.104	4·2	3·2
MM.105	3·9	4·2
MM.106	3·3	2·8
M.IV	2·7	2·5
M.VII	3·1	2·6
M.IX	3·0	1·7
Spy	3·1	2·6
Sig. diff. (P=0·05) ..	0·45	0·93
	Trial B	Trial D
MM.107	1·7	2·7
MM.108	2·3	2·4
MM.109	2·1	2·0
MM.110	3·2	4·2
MM.111	2·5	2·7
MM.112	2·1	2·7
MM.113	3·8	4·0
MM.114	4·3	4·5
MM.115	4·0	4·1
I.D.V.	3·5	3·6
M.I	2·0	2·6
M.II	1·7	1·5
M.IV	2·0	1·6
M.XVI	4·0	4·7
M.XXV	3·0	2·9
Sig. diff. (P=0·05)		
Maximum ..	0·82	
Minimum ..	0·75	0·60

Categories : 1=tree very loose ; 5=tree very firm.

Trees on M.IV are generally regarded as poorly anchored and those on M.XVI as well anchored, and the trees in these trials confirm this. It is clear that the anchorage of all the new rootstocks on the Malling soil series in Trial A, with the exception of MM.102, is better than that of M.IV. In Trial B, MM.110 and M.XXV were better anchored than were M.II and MM.113, MM.114 and the very vigorous MM.115 were as well anchored as was M.XVI. On the Bearsted soil series, in Trial C, the anchorage varied considerably and only MM.101, MM.103 and MM.105 were significantly better anchored than was M.IV ; but in Trial D, the rootstocks behaved similarly to those in Trial B.

Fruit buds.

The total number of fruit buds formed in the first five-year period after planting showed that trees on all rootstocks formed many more on the Malling than on the Bearsted soil series. Many of the new rootstocks were more precocious than some of the control rootstock varieties of comparable vigour, even though blossoms were produced relatively soon by the light pruning of trees on rootstocks such as M.XVI, which normally delay blossoming. Trees on the rootstocks MM.115 and M.XXV in the very vigorous group were much more precocious than were those on M.XVI. In the vigorous group also, trees on rootstocks MM.109 and MM.111, on the Malling soil series, were rather more precocious than were those on M.I and M.II. On the same soil, trees on MM.104 and M.VII produced more fruit buds than did those on the early and heavy-bearing rootstock M.IV, but the reverse occurred on the Bearsted soil series. Fruit bud records were discontinued when trees on all rootstocks came into bearing.

Fruit set.

Fruit set data, estimated from the mean number of fruits harvested per 100 blossom clusters, are available for the years 1948, 1949 and 1950. In the very vigorous group of rootstocks, trees on M.XXV were outstanding during this initial period, the flowers setting much better than did those on either M.XVI or I.D.V. and slightly better than on the less vigorous trees on M.II.

Fruit yield and size.

Total fruit yields during the seven-year period for the four trials are shown in Table IV.

When comparing trees of similar vigour, certain of the new rootstocks induced heavier yields than did many existing ones during the establishment period. On the Malling soil series, for example, comparison may be made between the yields from trees on M.II and MM.111, also between those from trees on M.XVI and MM.115. The trees on MM.104 yielded as well as did those on M.IV, which has hitherto been outstanding among rootstocks for heavy bearing ; moreover, MM.104 does not possess some of the serious disadvantages of M.IV either in the nursery or in the field. During the five years 1948–52, trees on this new rootstock in Trial A averaged 196 lb. of fruit per tree.

Fruit size was well maintained, averaging 4 to 4½ fruits to the pound, and there were no obvious differences between rootstocks in either size or fruit colour ; this is noteworthy in view of the large yields, especially on the Malling soil series, and the fact that the fruit was not thinned.

TABLE IV.

Mean total fruit yield per tree (lb.) of three scion varieties, 1948–52

Rootstock	Malling series	Bearsted series
	Trial A	Trial C
MM.101	114·5	61·8
MM.102	115·0	36·6
MM.103	166·8	71·9
MM.104	196·3	69·4
MM.105	133·0	67·9
MM.106	127·9	51·3
M.IV	172·8	73·3
M.VII	134·1	61·9
M.IX	66·4	31·1
Spy	116·3	50·8
Sig. diff. (P=0·05) ..	26·3	16·9
	Trial B	Trial D
MM.107	91·3	59·2
MM.108	113·9	33·0
MM.109	146·7	82·8
MM.110	137·0	83·9
MM.111	153·1	69·5
MM.112	120·2	55·7
MM.113	143·4	68·5
MM.114	134·1	51·2
MM.115	170·1	63·6
I.D.V.	192·6	66·6
M.I	105·9	37·5
M.II	109·2	55·6
M.IV	193·5	67·9
M.XVI	120·0	57·1
M.XXV	158·0	66·8
Sig. diff. (P=0·05)		
Maximum ..	45·3	
Minimum ..	39·2	26·0

DISCUSSION.

The results of these trials have shown that, at seven years old, some of the new Malling–Merton rootstocks, in addition to their resistance to Woolly Aphid, have produced trees that are improvements on those on the older Malling clones. Whether these improvements will be maintained in future years remains to be shown.

The method of pruning used throughout the trials has made it possible to obtain useful data not only on vigour and cropping but also on anchorage, because of the large tree heads so formed. It will be noted, however, that the early cropping that has resulted from the light pruning of trees on very vigorous rootstocks has, up to the present, reduced the contrast which is normally expected between the vigorous and very vigorous groups of rootstocks. The heavy and early bearing is probably due not only to the absence of prolonged leader tipping, which was shown by Grubb (1922) to delay cropping, but also to the more effective blossom period associated with such lightly pruned trees where blossoms on three-, two-, and one-year wood have been shown to open successively after those on older spurs (Rogers and Preston, 1947).

Two severe summer droughts (1947 and 1949) should be borne in mind when evaluating the behaviour of trees on the Bearsted soil series. Indeed, the present position as regards vigour and total crop (Tables II and IV) may perhaps be taken as an indication of the ability of trees on certain rootstocks to withstand severe drought conditions. For example, trees on both M.II and MM.109 were badly affected by leaf scorch and premature defoliation ; those on the former are still considerably stunted, whereas those on MM.109 have grown away well and yielded more fruit than have the trees on M.II (Table IV). Trees on M.IX are also very small on the Bearsted soil series and some are definitely stunted ; rootstocks MM.102 and MM.106, however, have made trees larger than those on M.IX, yet significantly smaller than those on M.VII.

Some rootstocks in the very vigorous group do not propagate readily when stooled (Table I). Both MM.113 and MM.114 which are very vigorous and resistant to Woolly Aphid propagate poorly, a quality possibly inherited from their parents (Spy × M.XII). Also within this vigour group are trees on Ivory's Double Vigour, but although their cropping record is attractive, it is largely offset by the shy rooting of this rootstock when stooled. If trees on MM.115 maintain their present vigour it seems likely that this rootstock would fulfil the need for a Woolly Aphid-resistant rootstock in this group, as it does propagate readily. Trees on this rootstock have behaved well on both soils.

Some changes in relative vigour may be expected over the next few years ; these will indicate the most suitable planting distances on these widely different soils. Early vigour combined with good cropping may ultimately lead to trees of intermediate size on some of these rootstocks, as was shown to happen by Hatton (1935) with trees on M.IV and M.VII.

The new rootstocks have already been distributed for initial testing to research institutes abroad. It is very desirable that the whole range should be tested in each country, for there is ample evidence that the best rootstocks under English conditions are not necessarily the ones best suited to conditions overseas.

For fruitgrowers in England, five of the new rootstocks, MM.104, MM.106, MM.109, MM.111 and M.XXV, have been selected for distribution to nurserymen as foundation stock for multiplication. Their characteristics have already been summarized (Preston, 1953b).

Breeding for Woolly Aphid-resistant scion varieties for use on the new resistant rootstocks is already in progress at East Malling.

SUMMARY.

Results are presented, covering the first seven years, of field trials, on two widely differing soil series, of sixteen new clonal apple rootstocks. Bred jointly by the staffs of the John Innes Horticultural Institution and East Malling Research Station, they have been named the Malling–Merton rootstocks. Fifteen of the new rootstocks are resistant to Woolly Aphid and have been numbered Malling–Merton 101 to 115 (MM.101, etc.). Another promising new rootstock, not highly resistant to Woolly Aphid, will be known as Malling XXV (M.XXV).

The performance in the field of the new rootstocks up to seven years old, on two soil series, is described. Three scion varieties were included in the trials and all responded similarly. The relationship of the light system of pruning used to root-

stock effect is discussed. At this age some of the new rootstocks appear to be improvements on the older Malling clones.

The new rootstocks have been sent abroad for initial testing at research institutes and five of them have been distributed to fruit tree nurserymen in England for rapid multiplication ; these five are MM.104, MM.106, MM.109, MM.111 and M.XXV. All except M.XXV are resistant to Woolly Aphid.

ACKNOWLEDGMENTS.

These trials were initiated by Sir Ronald Hatton. The Woolly Aphid-resistance tests were carried out by Dr. A. M. Massee. Members of the Statistics Section carried out the analyses of variance. The help of all these and of many others is gratefully acknowledged.

REFERENCES.

Beakbane, A. B., and *Thompson, E. C.* (1939). Anatomical studies of stems and roots of hardy fruit trees. II. J. Pomol., **17,** 141-9.

———, ———, and *Tydeman, H. M.* (1941). Preliminary selection of apple rootstocks immune from Woolly Aphis based on certain anatomical differences in root structure. Rep. E. Malling Res. Sta. for 1940, 32-6.

Crane, M. B., Greenslade, R. M., Massee, A. M., and *Tydeman, H. M.* (1936). Studies on the resistance and immunity of apples to the Woolly Aphis *Eriosoma lanigerum* (Hausm.). J. Pomol., **14,** 137-63.

Furneaux, B. S. (1954). The soils of East Malling Research Station. Rep. E. Malling Res. Sta. for 1953, 60-82.

Garner, R. J. (1953). The nursery behaviour of the Malling–Merton and M.XXV apple rootstocks. Rep. E. Malling Res. Sta. for 1952, 64-6.

Grubb, N. H. (1922). Winter pruning experiments with apple trees. J. roy. hort. Soc., **47,** 139-62.

Hatton, R. G. (1935). Apple rootstock studies. Effect of layered stocks upon the vigour and cropping of certain scions. J. Pomol., **13,** 293-350.

——— *et al.* (1937). The problems raised by the Woolly Aphis of the apple. A case for team research. Ann. appl. Biol., **24,** 169-210.

Pearce, S. C., and *Hoblyn, T. N.* (1948). A review of experimental design at East Malling, 1919–1947. Rep. E. Malling Res. Sta. for 1947, 88-100.

Preston, A. P., and *Stanton, D. J.* (1947). A soil survey of the new Bradbourne experimental orchards. Rep. E. Malling Res. Sta. for 1946, 55-61.

——— (1953a). Some new apple rootstocks. Proc. 13th int. hort. Congr. London, 1952, 267-81.

——— (1953b). Five new apple rootstocks. Rep. E. Malling Res. Sta. for 1952, 169-70.

Rogers, W. S., and *Preston, A. P.* (1947). Renewal and Established-spur pruning of mature apple trees. Rep. E. Malling Res. Sta. for 1946, 49-54.

Tydeman, H. M. (1953). A description and classification of the Malling–Merton and M.XXV apple rootstocks. Rep. E. Malling Res. Sta. for 1952, 55-63.

(*Received* 10/4/54.)

SOME EFFECTS OF TEMPERATURE AND DAY-LENGTH ON FLOWERING IN THE CHRYSANTHEMUM

By DAPHNE VINCE
Department of Horticulture, University of Reading

It has been reported that a period of low temperature, i.e. vernalization, is necessary for (or at least greatly accelerates) flowering in the chrysanthemum (Schwabe, 1950). A three-week period at 5–7° C. was effective in stimulating flowering. The varieties of *Chrysanthemum morifolium* Ramat. tested by Schwabe were " Sunbeam ", " Godfrey's Gem ", " Cossack " and " Blanche de Poitevine ", and in the absence of vernalization the flowering of each was delayed and the leaf number increased. In the variety " Sunbeam " there was a difference in leaf number of 86·1 between vernalized plants (28·6 leaves) and non-vernalized plants (114·7 leaves) grown in short days. When grown at high temperatures and with short days, all of these varieties exhibited a diageotropic habit of growth, except " Cossack ", which produced short, abnormally thick stems. Another species, *C. rubellum* Sealy, behaved in the same manner as *C. morifolium*.

No commercial mid-season or late-flowering decorative varieties of *C. morifolium* were included by Schwabe, and the response of one such variety was investigated in the experiments described here. A preliminary attempt was made to determine at what stage the period of low temperature could be effective, and whether the response to low temperature was influenced by the source of the cutting.

Materials and methods.

The variety grown in most of the experiments was *C. morifolium* " Magnet ", a November-flowering decorative type. Two experiments were also carried out with " Charm ", a dwarf sport from the " Cascade " chrysanthemum, which is descended from *C. indicum* L. (Balfour, 1947), to investigate the temperature requirements of a different type of chrysanthemum.

The plants were raised from cuttings selected for uniformity and, unless otherwise specified, taken from the base of the plants. The cuttings were rooted in a propagating frame at temperatures above 60° F. The plants were then grown at temperatures of 60° F. or above throughout, except during the low temperature treatments. Plants receiving short day treatments had 8 hours of daylight from 8 a.m. to 4 p.m. ; at 4 p.m. they were moved into dark chambers adjacent to the glasshouse range for the night. Plants having long day treatments remained in the greenhouse and were given supplementary light from 40 watt warm-white fluorescent tubes so that the total daylength was 17 hours.

In the first experiment the plants were vernalized by being placed in an unheated frame ; in the later experiments they were vernalized in a cold store. The cold period was given as soon as the rooted cuttings had been potted and were established.

After rooting, the cuttings were potted into 3½ in. plastic pots in John Innes potting compost No. 1, and later were re-potted into 6 in. clay pots in John Innes

potting compost No. 3. The plants were not stopped back, except in Experiment 4.

Records were kept of the date of appearance of the terminal bud, the date of anthesis and, except in Experiment 4, of the number of leaves to the inflorescence.

EXPERIMENTS 1 AND 2; 1952. VARIETY "MAGNET".

The treatments in both experiments were 1, Short-day, not vernalized; 2, Short-day, vernalized; 3, Long day, not vernalized; 4, Long day, vernalized. The number of replicates was 16.

Stools obtained from commercially grown plants, which had been kept for a short period after flowering at 45–50° F., were cut back on 24th January and all basal and stem shoots removed; after this they were kept at temperatures of over 60° F. in the glasshouse. Supplementary light from 40 watt warm-white fluorescent tubes was given throughout the night, at an intensity of 45–65 lumens per sq. ft. at soil level. Cuttings were rooted in long or short days and maintained in these daylengths subsequently.

The cuttings for Experiment 1 were taken on 15th February. The low temperature treatment was given in a cold frame from 10th March to 21st April, when the following temperatures were recorded:

Mean daily temperature at 8 a.m. .. 47·4° F.
Mean daily minimum .. .. .. 44·5° F.
Mean daily maximum .. .. 61·2° F.

The possibility of a carry-over of a low temperature effect from the period during which the stools were kept at 45–50° F. could not be eliminated in Experiment 1. To reduce this possibility in Experiment 2, the cuttings were taken from the second batch of shoots appearing on the stools, which by this time had been kept at high temperatures for five weeks. The vernalizing treatment (37° F. in darkness) was given from 9th to 30th April.

TABLE I.

Effect of length of day and vernalization on leaf-form: variety "Magnet".

	Long days		Short days		Significant difference between means P=0·05
	Vernalized	Not vernalized	Vernalized	Not vernalized	
Experiment 1. 30th May					
Leaf area—cm.² ..	72·0	93·5	49·7	44·4	8·9
Leaf length—cm. ..	14·8	16·5	15·1	13·7	1·0
Leaf width—cm. ..	10·4	11·6	9·4	8·1	0·8
Ratio area/length ..	4·6	5·7	3·2	3·2	0·4
Experiment 2. 14th Aug.					
Leaf area—cm.² ..	75·1	80·6	57·4	54·6	9·0
Leaf length—cm. ..	16·0	17·8	15·3	15·9	0·9
Leaf width—cm. ..	10·2	10·9	8·8	8·8	0·8
Ratio area/length ..	4·7	4·5	3·8	3·4	0·4

Results.

In both experiments the plants in long days grew more rapidly and were taller than those in short days. The leaf form in the two daylengths was noticeably

different. In short days the leaves were elongated and tended to curl under from the tips and margins. In long days the leaves were larger and the leaf blades were flat. One leaf was taken from the centre of each plant in each experiment and measurements were made of length, area and width.

The most striking differences shown in Table I are those between leaves grown, respectively, in long and short day conditions ; the differences due to temperature are small. The leaves from plants in long days were longer, wider and greater in area than those from plants in short days, and the ratio of leaf area to leaf length was also significantly greater.

In continuous long days the plants formed terminal inflorescence buds which failed to develop to anthesis ; apical dominance was lost and vegetative shoots grew out below the terminal buds. These results agree with those of Schwabe (1951), Chouard (1949), and Behrens (1949). Popham and Chan (1952) have, however, suggested that inflorescence initiation can only occur if a limited number of (probably fewer than five) short photo-periods is given. In the short day treatment all terminal buds developed to anthesis.

TABLE II.

Effect of vernalization and length of day on flowering : variety " Magnet ".

	Long days		Short days		Significant difference between means P=0·05
	Vernalized	Not vernalized	Vernalized	Not vernalized	
Experiment 1					
Leaf number to inflorescence ..	38·4	42·6	34·5	33·2	3·7
Days to visible bud from 21st April, 1952	52·3	52·8	38·9	33·0	10·6
Experiment 2					
Leaf number to inflorescence ..	41·0	45·1	34·0	34·8	3·1
Days to visible bud from 30th April, 1952	83·5	80·3	64·9	47·3	7·0

The number of leaves to the inflorescence was greater in long days than in short days ; in the two experiments 6·6 and 8·6 more leaves respectively were laid down in long days than in short days before the inflorescence was initiated. In short days the temperature treatments had no effect on leaf number, but in long days the leaf number was significantly greater in the non-vernalized plants. Thus, in a daylength unfavourable for the initiation of inflorescence primordia, the low temperature treatment substituted in part for the daylength requirement in this variety.

The appearance of the bud was delayed in long day compared with short day conditions. In long day, the temperature treatment had no effect on the date of budding, since the check to growth during the period of low temperature was compensated for by the smaller number of leaves laid down before the inflorescence was initiated. In short day, where the leaf number was not influenced by temperature, there was no difference in the date of budding between temperature treatments in Experiment 1, where the check to growth was less severe. In Experiment 2, where the check to growth during the three-week period in cold store was very severe, the

appearance of the bud in the cooled plants was delayed by 17·6 days, or approximately the same period as the plants were in the cold store.

Commonly a few chrysanthemum plants form a terminal bud after only a few leaves have been laid down. The factors controlling such premature bud formation are not known. Nine plants in the two experiments produced buds when from 5 to 16 leaves had been formed, instead of the normal 30–40. These buds did not develop even in short days, though dissection showed that floret initiation was nearing completion. The plants occurred in all treatments and are not included in the results presented here.

In these two experiments the variety "Magnet" showed no low temperature requirement, inflorescence primordia being initiated in both short and long days in the absence of any low temperature treatment. The possibility of a carry over of a low temperature effect from the pre-treatment of the stools cannot, however, be ruled out.

At the end of the experiments the plants had been grown for ten months, and flowered at temperatures above 60° F. After flowering in August and September the plants from Experiment 2 were cut back; half of these stools were placed outdoors, the remainder being kept at high temperatures in the glasshouse. On 24th October the outdoor stools were returned to high temperatures. Subsequently both sets were treated alike, all basal and stem shoots being removed and the cuttings allowed to develop at temperatures above 60° F. These cuttings provided the material for Experiment 3.

EXPERIMENT 3; 1952–53. VARIETY "MAGNET".

A $2 \times 2 \times 3$ factorial experiment was set up, with 6 replicates in each treatment; the treatments were:

1. Position of cutting: (*a*) basal,
   (*b*) stem.
2. Temperature pre-treatment of the parent stools:
   (*a*) cool conditions from flowering to 24th October,
   (*b*) not cooled.
3. Temperature treatment during growth of plants:
   4 weeks, 14th January to 11th February, 1953
   (*a*) 40° F. ±2° F. in cold store: 10 hour day,
   (*b*) Mean minimum 49·5° F. in glasshouse: natural day 9–11 hours,
   (*c*) Mean minimum 60·2° F. in glasshouse: natural day 9–11 hours.

Uniform cuttings were selected on 17th November, 1952. All the plants were maintained in short days until 11th February, and were subsequently given long day treatment for a four-week period from 11th February to 11th March, 1953. A period of long days at this stage has been shown to accelerate the process of flower initiation (Schwabe, 1952): it does not substitute for vernalization. On 11th March the plants were transferred to short day conditions until flowering.

Results.

At the date of the first potting (10th December) the plants from the stools which had remained throughout at high temperature showed a marked tendency to rosette,

TABLE III.

Effect of temperature, origin of cutting and pre-treatment of the parent stool on flowering : variety " Magnet ".

Origin of cutting ..	Basal cuttings						Stem cuttings						Significant difference between means P=0·05
Temperature pre-treatment of stools ..	Not cooled—from flowering to 24th October at 60° F.			Cooled—from flowering to 24th October out of doors			Not cooled			Cooled			
Temperature during vernalizing period from 14th January to 11th February	40° F.	49·5° F. min.	60·2° F. min.	40° F.	49·5° F. min.	60·2° F. min.	40° F.	49·5° F. min.	60·2° F. min.	40° F.	49·5° F. min.	60·2° F. min.	
No. of weeks to visible bud from 28th March	3·8	3·7	5·0	4·2	2·3	4·5	4·3	4·0	5·0	4·5	3·3	4·7	1·3
No. of days to anthesis from 15th May ..	22·5	6·5	21·3	21·2	11·7	22·5	18·0	14·7	23·5	17·7	3·8	19·8	9·4
Leaf no. to inflorescence	37·7	41·3	45·2	36·5	40·3	40·7	37·2	42·5	47·0	40·7	41·0	41·3	3·7

Significance level reached	Main effects			Interaction
	Origin	Stool temperature (S)	Vernalization temperature (T)	S×T
No. of weeks to bud			P=0·001	
No. of days to anthesis ..			P=0·001	
Leaf no. to inflorescence ..		P=0·05	P=0·001	P=0·01

whether the plants were derived from basal or stem cuttings, whereas the plants from the stools which had been cooled were normal in appearance. By the beginning of January the difference between the plants was less pronounced, but the rosetted habit was still apparent in the plants from non-vernalized stools. Later the difference in habit became less marked and at flowering time there was little observable difference between the two sets of plants. At no time did the plants exhibit diageotropic growth.

All three characters recorded were significantly affected by the low temperature treatment, which resulted in an acceleration of flowering and a reduction in leaf number. Both temperature treatments significantly reduced the leaf number, but the four-week period at 40° F. was more effective than that at 49·5° F. minimum. The differences in leaf number, however, although highly significant, were in fact rather small, the maximum difference between temperature means being 8·7 leaves. This may be compared with differences in the variety "Sunbeam" of the order of 86 leaves.

The earliest date of anthesis was in the 49·5° F. minimum treatment: the plants vernalized for four weeks at 40° F. flowered at the same time as those grown without vernalizing, since the extra number of leaves laid down was compensated for by the check to growth during the period at lower temperature. The difference in the time of flowering was, however, only 11·6 days.

The only significant interaction was between the stool temperature and the temperature treatments during growth. The low temperature treatment had no effect on plants obtained from stools which were cooled after flowering. The effect of the low temperature must therefore have been carried over from the parent stool, even though the cuttings developed at high temperature. The origin of the cuttings had no effect on the response of the plants to low temperature, both basal and stem cuttings responding in the same manner.

EXPERIMENT 4; 1952. VARIETY "CHARM".

The cuttings were taken on 30th January from two stools of seedling plants, treated after flowering as the stools in Experiment 1. The plants were flowered in 5 in. pots, and were stopped back once—the normal stopping treatment for this variety. Otherwise the treatments and conditions were as in Experiment 1, except that the number of replicates in each treatment was 10.

TABLE IV.

Effect of vernalization on flowering: variety "Charm". Plants grown in short days (8 hours).

	Not vernalized	Vernalized	Significance level
No. of days to appearance of bud from 22nd April, 1952	33·5	59·2	P=0·05
No. of days to anthesis from 22nd April	69·4	107·6	P=0·01

Results.

By 13th May, most of the vernalized plants in short day conditions were showing buds, but none were yet visible on the vernalized plants or on the plants in long days.

Bud formation occurred subsequently in all treatments, but in long days the buds did not develop to anthesis. In short days the plants flowered rapidly, showing no low temperature requirement. A period of low temperature during growth delayed the appearance of buds and of flowers.

EXPERIMENT 5; 1952–1953. VARIETY "CHARM".

The possibility of a carry over of an effect of the low temperature pre-treatment of the stools again cannot be eliminated in Experiment 4. After flowering the plants were cut back and the stools kept at a temperature of over 60° F. Basal cuttings from these stools were selected on 17th November, 1952.

As this variety is easily and, in fact, usually raised from seed, plants grown from seed (sown on 24th October, 1952) were included in the experiment since there seemed no possibility of these having been vernalized. Their response to low temperatures was compared with the response of the plants raised from cuttings. The treatments were, therefore:

1. Vernalized for four weeks (14th January to 11th February) at 40° F. ±2° F.
   (*a*) Plants raised from cuttings,
   (*b*) Plants raised from seed.
2. Not vernalized—plants remained in the glasshouse throughout
   (*a*) Plants raised from cuttings,
   (*b*) Plants raised from seed.

Eight plants were grown in each treatment.

Except for the period from 14th January to 11th February, when they were kept in short days, all plants were grown in long days until 11th March. On this date they were transferred to short day conditions until anthesis. The plants were flowered in 5 in. pots and grown unstopped.

Results.

The plants raised from cuttings were rosetted in appearance when they were first potted on 1st December, but at flowering time there was no difference in habit between plants from different treatments.

TABLE V.

Effect of vernalization on flowering of plants raised from seed and cuttings: variety "Charm". Plants grown in short days.

Origin of plant	Seed		Cutting		Significant difference between means
Temperature during vernalizing period from 14th Jan. to 11th Feb.	40° F.	60° F.	40° F.	60° F.	P=0·05
No. of weeks to bud from 20th March	3·0	1·8	3·1	2·1	0·7
No. of days to anthesis from 29th April	18·8	7·1	21·8	10·6	8·1
Leaf number to the inflorescence	34·4	36·2	38·4	42·1	4·7

The times of budding and flowering were delayed in plants given a period of low temperature, whether the plants were raised from seed or from cuttings. The leaf number was not significantly different between treatments, however, showing that

the effect of the low temperature in delaying flowering was non-specific. The effect of the origin of the plant (from seed or cuttings) reflects the variability in the leaf numbers of the material raised from seed : the plant from which the clone was raised had a higher leaf number than the mean leaf number of the plants raised from seed.

This variety apparently has no requirement for low temperature, whether raised as a new generation from seed, or vegetatively from parent material grown and flowered at high temperatures.

DISCUSSION.

From the results of these experiments it seems that some varieties of chrysanthemum do not have a marked low temperature requirement, and that at least one variety, " Charm ", flowers most rapidly if kept continuously at temperatures above 60° F. This may apply to the " Cascade " chrysanthemum generally, since "Charm" is a dwarf sport from this variety. Several varieties have been grown here under observation, and there is a striking difference in the behaviour of varieties such as " Sunbeam " and " President ", where terminal inflorescence initiation is delayed for months in the absence of vernalization, and the variety " Magnet ", in which anthesis is delayed by only about two weeks. Without vernalization, the growth of the variety " President " is abnormal and markedly rosetted, but not diageotropic as is the variety " Sunbeam ". In view of the great difference in the behaviour of the few varieties studied closely, it would be of interest to know which of our main commercial varieties require vernalizing to any considerable extent, especially with regard to the recently introduced practice of growing late-struck cuttings which are planted and flowered under glass and may, therefore, receive insufficient cold. Probably there is no clear cut division into two types, the varieties grading from those requiring no vernalizing to those to which vernalization is essential, with all types of intermediate low temperature requirement between.

The experiments on the variety " Magnet " prove that the effect of subjecting the parent stools to low temperatures can be carried over into the cuttings, even though these may be produced at high temperatures. Maintaining the stools in cool conditions after flowering until the cuttings are taken should, therefore, satisfy any low temperature requirement.

The temperature control was not exact enough to determine the highest temperature effective in reducing leaf number. A four-week period at 40° F. was more effective than at 49·5° F. minimum, but the latter temperature significantly reduced leaf number. Since in this treatment the day temperature was above 49·5° F., whereas in the 40° F. treatment the temperature was maintained continuously, it is possible that a temperature of 50° F. applied continuously might be as effective in vernalizing the chrysanthemum plant as 40° F.

SUMMARY.

The responses of two chrysanthemum varieties, " Magnet " and " Charm ", to daylength and temperature were investigated.

A period of low temperature was not found to be necessary for flowering in the variety " Charm " ; any period of low temperature during growth actually delayed flowering.

The variety " Magnet " showed a limited requirement for low temperature : a maximum decrease of 8·7 leaves occurred when plants were given four weeks at 40° F. compared with plants grown at 60° F. A period of four weeks at 49·5° F. minimum also decreased the leaf number, but was less effective than four weeks at 40° F. The flowering date was not accelerated by the 40° F. treatment because of the slower growth rate during the period at this temperature. The 49·5° F. minimum treatment accelerated flowering very slightly.

On material taken from stools subjected to a period of low temperature, a further period of low temperature (6 weeks in a cold frame, or 3 weeks at 37° F.) reduced the leaf number by four in long days. In short days the further period of low temperature had no effect.

In " Magnet " the effect of a low temperature treatment of the parent stools was carried over to the cuttings, even though these were produced at high temperatures. There was no difference in response to temperature between plants raised from stem cuttings and those raised from basal cuttings.

In continuous long days (17 hours) from the cutting stage, initiation of inflorescence primordia occurred in both varieties after a delay. In long day conditions the development of the bud was arrested, and apical dominance lost.

The leaf character of " Magnet " differed in plants grown in long day (17-hour) and short day (8-hour) treatments. In continuous short days the leaf blades failed to expand normally and the leaves curled under. The leaves were narrower and shorter than those in long days and the leaf area was reduced proportionally more than the leaf length.

REFERENCES.

Balfour, A. P. (1947). Charm chrysanthemums. J. roy. hort. Soc., **72,** 17.

Behrens, G. (1949). Blüten und Gestaltsbildung bei Chrysanthemum und Sempervivum unter photoperiodischen Einflüssen. Biol. Zbl., **68,** 1.

Chouard, P. (1949). Pourquoi fleurissent les plantes ? Les conférences du Palais de la Découverte. Université de Paris.

Popham, R. A., and *Chan, A. P.* (1952). Origin and development of the receptacle of *Chrysanthemum morifolium.* Amer. J. Bot., **13,** 706.

Schwabe, W. W. (1950). Factors controlling flowering in the chrysanthemum. I. Effects of photoperiod and temporary chilling. J. exp. Bot., **1,** 329.

——— (1951). Factors controlling flowering in the chrysanthemum. II. Daylength effects on further development of inflorescence buds and their experimental reversal and modification. J. exp. Bot., **2,** 223.

——— (1952). Factors controlling flowering in the chrysanthemum. III. Favourable effect of limited periods of long-day on inflorescence initiation. J. exp. Bot., **3,** 430.

(*Received* 5/4/54.)

STEAM PRESSURE IN SOIL STERILIZATION
II. GLASSHOUSE *IN SITU* STERILIZING

By A. C. BUNT
John Innes Horticultural Institution, Hertford

STEAM sterilization of glasshouse soils is now a well-established practice. Since its introduction over fifty years ago, steam has generally been supplied by mobile, high pressure, locomotive type boilers working at pressures of 60–120 lb./sq. in. It has long been known that high pressure is not essential in steam sterilization of soil. Senner (1934) found that a pressure of ½ lb./sq. in. was sufficient to overcome soil resistance and Jens Roll-Hansen (1949) reported that boilers working at 7 lb./sq. in. were commonly used in Norway.

Recent interest in low pressure steam for glasshouse heating has focused attention on the possibility of utilizing this source of steam. The effect of different steam pressures has been studied by Senner (1934) in the U.S.A. with the inverted pan and buried tile systems but these are seldom used in this country. Fawcett (1949) found with the Hoddesdon pipe system that when the steam pressure at the header was reduced below the usual working range of 10–15 lb./sq. in., the heating period was increased. From general observations it was thought that fuel consumption was less at the lower pressures. Enkel (1948), describing equipment used by him for contract steam sterilization, stated that when high pressure boilers were used a reducing valve was included. This was set, by trial and error, to give a 12-minute heating period. Gamble (1948) recommended the use of a pressure-reducing valve to ensure a steam pressure of 5 lb./sq. in. at the header.

As little critical information was available, an investigation was started by the author in 1950 to study all aspects of the effect of steam pressure on the sterilization *in situ* of glasshouse soil. Since this work began, the National Institute of Agricultural Engineering has published the results of a laboratory study on the application of steam to soils (Morris, 1952). This work deals with the physical aspects of soil sterilization. The specific heat, density and heat requirements of soils having different moisture contents are discussed. It was concluded that boiler pressures of any value could be used provided the maximum output could be delivered to the Hoddesdon pipes with a pressure in them of about 5 lb./sq. in. There was a small advantage in favour of low pressure steam but, as the work was carried out under laboratory conditions, the effect of pressure variations would not be so large as under glasshouse conditions and the difference in the results would be minimal.

EQUIPMENT.

Steam was supplied by a Robey No. 24 locomotive type boiler, having a maker's rated evaporative capacity of 1,500 lb. steam per hour at a maximum pressure of 120 lb./sq. in. The boiler was oil-fired and pressure automatically controlled by a pressure-stat. The steam was taken a distance of 100 yds. to the glasshouses by a permanent 3 in., underground, lagged steam main. This main, in the form of a " header ", was sited at the end of each block of glasshouses. Steam volume was

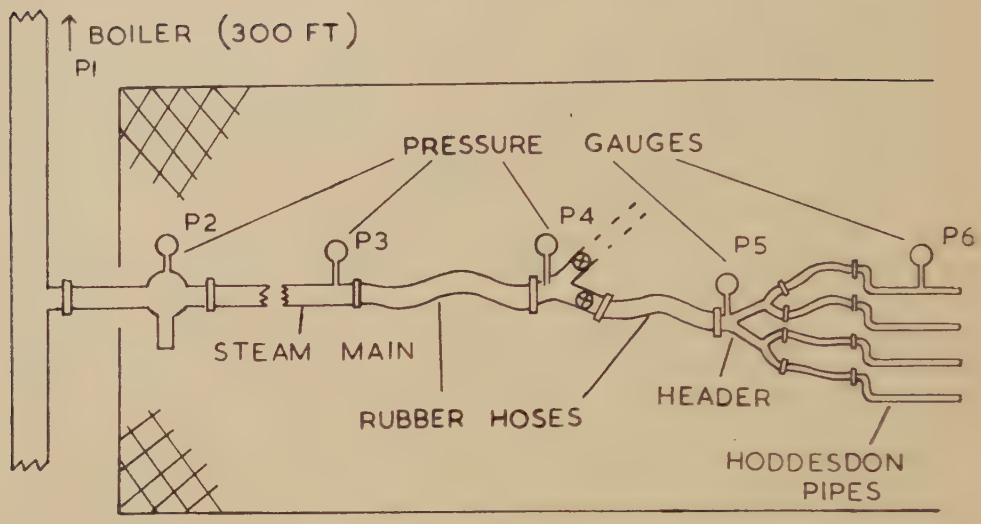

FIG. 1.
Layout of steaming equipment.

measured by a Kent 2 in. RS/C flowmeter fitted at the entrance to the glasshouse under test (Fig. 1). The water used by the boiler was measured with a Leeds H.W. rotary meter, and oil consumption with a Kent rotary oil meter. These instruments have an accuracy of ± 2 per cent. Steam pressure at points between the boiler and the Hoddesdon pipes (Fig. 1) was measured with Bourdon-tube type pressure gauges. Pressures below 10 lb./sq. in. were measured by manometers. Steam dryness at the headers was determined by the bucket calorimeter method described by Lyle (1947). The values for steam dryness given in this paper were obtained after a number of attempts had resulted in reasonably consistent readings. The steam drier used in the experiment operated on the centrifugal principle.

Two sets of sterilizing equipment were used. A low pressure set of 2 in. diameter steel mains, 2 in. rubber hoses and 2 in. triple-Y type steam headers, and a high pressure set of $1\frac{1}{2}$ in. steel mains, $1\frac{1}{4}$ in. rubber hoses and $1\frac{1}{4}$ in. triple-Y steam headers. The Hoddesdon pipes, 5 ft. 6 in. in length with 0·125 in. orifices 5 in. apart, were similar in design to those described by the Ministry of Agriculture Bulletin No. 22 (1947). The total calculated orifice area per pipe was 0·344 sq. in. The $1\frac{1}{4}$ in. rubber hoses connecting the pipes to the headers were common to both systems.

EXPERIMENTAL.

Equipment investigation.

The experiment had as its secondary objective the examination of the effects of a range of boiler pressures on rates of flow of steam and pressure losses at selected points. The data for the low pressure (2 in.) system are presented in Fig. 2 and Table I. Steam pressures given in this paper have been measured above atmospheric pressure.

For the equipment used in these experiments the boiler evaporation rate (E) can be expressed as a function of the boiler pressure, $E = 114P^{0.64}$, or of the header

TABLE I.

Steam flow rates and mean pressures at selected points.

Pressure (lb./sq. in) at							
Boiler	P1	10·0	15·0	20·0	30·0	45·0
Meter	P2	5·0	6·5	8·2	11·8	17·5
End of main	P3	2·4	4·3	5·6	9·6	16·3
Header	P5	1·5	2·4	3·5	6·0	11·0
Hoddesdon pipe	P6	1·0	1·8	2·6	4·5	7·5
Steam flow rate lb./hr.		500	640	780	1,000	1,300

The approximate lengths and diameter of steam main and rubber hoses used for the above determinations were :
P1—P2 300 ft. × 3 in. pipe, P2—P3 60 ft. × 2 in. pipe, P3—P5 21 ft. × 2 in. rubber hose, P5—P6 6 ft. × 1¼ in. rubber hose and 6 ft. × 1¼ in. pipe.

pressure, $E=419P^{0.48}$, or of the Hoddesdon pipe pressure, $E=493P^{0.47}$. The drop in pressure recorded in the 2 in. main between the steam meter and the header (P2 and P5 in Fig. 1) at the low rates of flow was considerably greater than that which can be attributed to frictional loss as calculated from either Lyle (1947) or the Babcock formula. The relationship between the boiler evaporation rate and the calculated drop in pressure between these two points can be expressed as $E=346P^{0.67}$, whereas the observed relationship was $E=79P^{1.48}$. Lack of back pressure in the system is the probable cause of this large pressure drop at the low flow rates.

Comparison was made between the high and low pressure systems for steam flow rates and pressure losses with the boiler working at 30 lb./sq. in. The low pressure system gave a 52 per cent. higher steam flow rate and 2·5 lb./sq. in. higher header pressure. Because of the large diameter steam mains the frictional drop in pressure

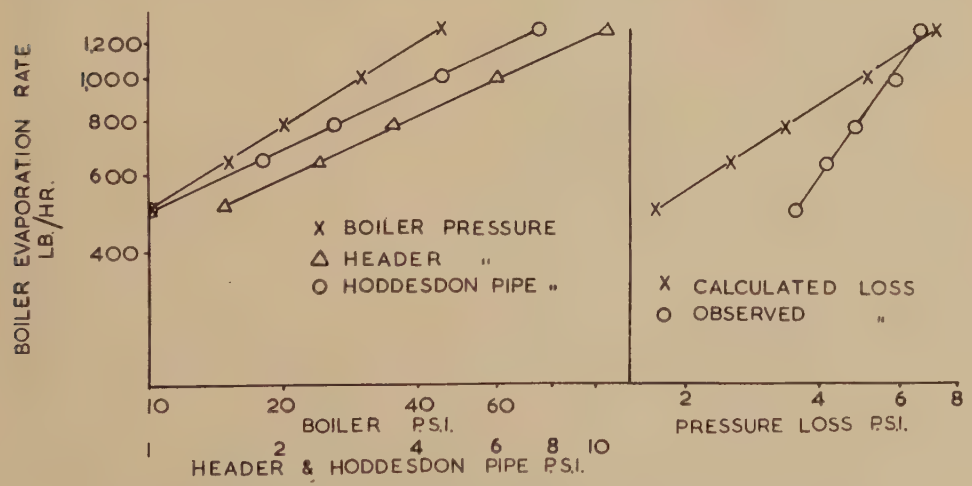

FIG. 2A. (Left).
Steam flow rates with corresponding pressures at selected points in the system.

FIG. 2B. (Right).
The calculated and observed pressure losses between the steam meter and the header over a range of steam flow rates.

between the boiler and the header was reduced to the minimum and it was possible in these experiments to obtain high header pressures when the boiler pressures were below the normal working range of high pressure boilers. For example, with the high pressure system a boiler pressure of 60 lb./sq. in. gave 10 lb./sq. in. at the header, whereas the low pressure system when operated at a lower boiler pressure, 45 lb./sq. in., gave 11 lb./sq. in. at the header.

Steam quality is of considerable importance in soil sterilization. The presence of water in the steam indicates that heat has been lost in the steam main and, unless suitable provision is made for its removal, this steam and water mixture may lead to a deterioration in soil tilth around the pipe by a reduction in soil pore space. The increased soil resistance results in a build-up of steam pressure with the consequent formation of a steam jet. Usually the jet runs along the horizontal pipe and escapes into the open trench.

It has often been contended that under practical conditions low pressure steam is wetter than steam at high pressure. An attempt was made, therefore, using two independent methods, to compare the quality of low and high pressure steam at the header. Firstly, the amount of water removed by a steam drier was measured, and secondly, steam dryness was determined by the bucket calorimeter method. The results of these tests are given in Table II. Unfortunately, neither method can be regarded as giving true steam dryness. The efficiency of the drier is unknown and will vary with changing steam velocities, and the calorimeter method suffers from the inherent difficulty of obtaining a true steam sample. Nevertheless, from the results obtained there would not appear to be any significant difference in quality when the steam main is adequately insulated and steam traps fitted at strategic points. The steam velocities, even at low pressures, are high and this would tend to keep the steam dry.

The observed rate of steam flow from a single Hoddesdon pipe over the range of pressures used, was found to be in agreement with the calculated rate given by Morris (1952).

TABLE II.

A qualitative comparison of high and low pressure steam at the header as determined by (a) steam drier, and (b) calorimeter.

Header pressure (lb./sq. in.)	0·8	3·8
Steam flow rate, lb./hr.	370	790
Steam velocity, in 2 in. main* ft./sec.	120	230
Water (lb.) removed by steam drier per 100 lb. steam ..	3·9	3·1
Per cent. dryness by calorimeter	90	91

* Steam velocity has been calculated from the mean pressures in the line (Lyle, 1947).

Pressure comparisons.

A pilot experiment was designed for the purpose of comparing the high and low pressure systems, each being worked at two boiler pressures. A crop of lettuce grown in the glasshouses prior to sterilization had been watered with a trickle system of irrigation which left the soil wet and with a poor tilth. This was responsible for the large amounts of steam used. The Hoddesdon pipes were spaced at 17 in. and

placed at a depth of 10 in. in the compacted soil, giving a 12 in. cover of loose soil. The bottom of each trench was loosened by forking before the pipes were placed in position. The soil in these experiments was a boulder clay recently broken up from parkland and had the following mechanical analysis :

Coarse sand	22·4	Carbonates ..	1·3
Fine sand	23·4	Air-dry moisture	3·8
Silt	15·0	Loss by solution	1·9
Clay	27·0	Difference ..	+5·2
			100·0

Moisture content at field capacity	53%
Moisture content at permanent wilting	20%

At the start of the pilot experiment the customary procedure was followed of leaving the steam turned fully on for a 10 minute period after the soil temperature had been brought to 100° C. It was apparent from the amount of steam which escaped to the atmosphere that once the soil was at 100° C. heat was not being extracted from a very large amount of the steam subsequently passed. It was found that by reducing the steam flow to a trickle for the 10-minute period savings were obtained of from 1·9 lb. to 4·1 lb. of steam per cubic foot of soil. This includes an allowance for steam spread below the pipes. The quantity of steam saved depended on (*a*) the steam pressure being used, and (*b*) the amount by which the flow rate was reduced.

Following this technique, the time taken to steam a given area was reduced by turning on a second set of pipes as soon as the " trickle finish " for the first set had commenced.

Table III.

Summary of steam pressure comparisons with high and low pressure equipment, 1950.

	High pressure system (1½ in.)		Low pressure system (2 in.)	
	House No. 7B 35% moisture		House No. 7A 37% moisture	
Boiler pressure (lb./sq. in.)	60	30	30	15
Header pressure (lb./sq. in.)	10·0	4·0	6·5	3·0
Mean boiler evaporation rate (lb./hr.)	1,340	660	1,030	640
Mean rate of steam injection (lb./hr./sq. ft.) ..	43·0	21·2	33·2	20·6
Mean steam lb./cu. ft. soil	12·0	8·9	11·2	9·0
Decrease in steam at low pressure	—	26%	—	19·7%
Mean time to 100° C. (minutes)	16·0	24·0	19·3	25·0
Increase in time at low pressure	—	50%	—	29%

The 1950 results of steaming with the high and low pressure systems are presented in Table III. These show that with each comparison the lower boiler pressure gave a saving in steam but the time per plot was increased. The investigation into the effect of different pressures was continued the following year and, in addition, rotary cultivation and hand preparation of the soil prior to sterilization was included.

TABLE IV.

Sieve analysis of rotary cultivated and hand-dug glasshouse soil prior to sterilization (percentage by weight)

House	Cultivation	Sieve size				
		> 1½ in.	< 1½ in. > ¾ in.	< ¾ in. > ⅜ in.	< ⅜ in. > 5/16 in.	< 5/16 in.
7A	Hand dug ..	22·2	14·0	12·6	3·6	47·4
	Rotary cultivated	3·4	6·5	15·1	5·5	69·5
7B	Hand dug ..	27·0	19·8	12·6	3·8	36·8
	Rotary cultivated	1·5	12·3	17·5	4·6	64·0

The low pressure (2 in.) system only was used and the experiment was set out to give six replications for hand-dug and rotary cultivated soils at each pressure. The type of treatments did not, however, permit adequate randomization. The soil tilths prior to sterilization were compared by a sieve analysis, Table IV. A difference in soil moisture levels between the two houses did not permit a thermal efficiency comparison between all pressures. The soil moisture content was 36 per cent. of the oven dry weight for the 10 and 30 lb./sq. in. boiler treatments and 32 per cent. for the 20 and 45 lb./sq. in. treatments. If the heat requirement of these soils is taken as 39 and 35 B.T.U.s/cu. ft./° F. the calculated difference in the extra steam required for the wet soil is 0·62 lb./cu. ft. During steaming it was observed that the loss of uncondensed steam from the soil being sterilized at the higher pressures was greater than the loss at the lower pressures. There was also a tendency with the wet soil to lose steam by " puddling " and " blowing " at the high pressure. No blowing occurred on the drier soil even when a higher pressure was used. The full summary of this experiment is given in Table V. The differences between the quantity of

TABLE V.

Summary of two pressure comparisons at two soil moisture levels, 1951.

	House 7B Soil moisture 36%		House 7A Soil moisture 32%	
Boiler pressure (lb./sq. in.)	10	30	20	45
Header pressure (lb./sq. in.)	1·5	6·0	3·5	11·0
Hoddesdon pipe pressure (lb./sq. in.) ..	1·0	4·5	2·6	7·5
Boiler evaporation rate (lb./hr.)	500	1,000	780	1,300
Mean steam (lb./cu. ft. soil)	7·2	10·7	6·1	8·5
Decrease in steam	33%	—	28%	—
Mean time to 100° C. (min.)	22·5	17·2	12·7	10·2
Increase in time	31%	—	25%	—
Oil (gal./treatment)	30·6	47·5	28·7	41·5
Water (gal./treatment)	320	480	275	420
*Overall thermal efficiency (%)	53·5	34·5	51·0	35·4
Mean rate of steam injection (lb./hr./sq. ft.)	18·9	37·8	29·4	49·0

* Overall thermal efficiency has been calculated from :

$$\frac{\text{Vol. of soil/gal. oil} \times \text{soil heat capacity} \times \text{temperature rise}}{\text{Total calorific value of oil}}$$

Table VI.

Two-year summary of steam pressure comparisons.

	1952				1953			
	High pressure		Low pressure		High pressure		Low pressure	
Header pressure (lb./sq. in.)	6·0		0·9		3·8		0·8	
Hoddesdon pipe pressure (lb./sq. in.)	4·5		0·7		2·8		0·6	
Mean boiler evaporation rate (lb./hr.)	1,000		400		790		370	
Mean rate of steam injection (lb./hr./sq. ft.)	32·2		12·9		28·7		13·5	
	Dry soil 21%	Wet soil 29%	Dry soil 21%	Wet soil 29%	Dry soil 21%	Wet soil 30%	Dry soil 21%	Wet soil 30%
Mean steam (lb./cu. ft.)	5·7	6·3	4·7	5·2	5·8	7·2	4·9	5·6
Mean time (min.) per plot	10·5	11·6	21·5	23·5	11·9	14·6	21·4	24·5

steam per cubic foot of soil for the high and low pressure treatments in each pressure comparison are statistically significant ($P=0·001$). Rotary cultivation of the soil prior to sterilization gave a significant reduction ($P=0·05$) in the quantity of steam used in the 20 and 45 lb./sq. in. comparison. With the 10 and 30 lb./sq. in. comparison there was no significant difference. The boiler used in these experiments was fitted with a " long and short flame " type of oil burner and a thermal test showed an efficiency of 77 per cent. with the long flame and 55 per cent. with the short flame. This drop in thermal efficiency with the short flame was caused by lack of secondary air control. The quantity of oil used per treatment, Table V, has been corrected for a constant thermal efficiency of 77 per cent.

The comparison of high and low pressure steaming was continued for a further two years, 1952 and 1953, Table VI. No lettuce crop had been grown prior to sterilization as in the previous years, and this resulted in a much drier and warmer soil with a lower heat requirement. Each experiment comprised four treatments, two pressures and two moisture contents, with eight observations per treatment. The wet soils were obtained by bringing some of the dry plots to field capacity and allowing them to dry out to the desired moisture content. The differences in the quantity of steam used for the high and low pressure treatments were statistically significant ($P=<0·001$) for both years.

The effect of a range of boiler pressures on two soils having different moisture contents was next examined, cf. Fig. 3. It will be noticed that for both soils the quantity of steam used per cubic foot of soil increases as the steam injection rate into the soil is increased. Also, the rate of increase with the dry soil is greater than with the wet. This supports the view that *very* dry soils are not as easily sterilized as moist soils, especially at high rates of steam injection. It is apparent that low pressure steam gives the highest thermal efficiency, but from the data so far presented it is not clear whether this is due to the lower pressure at which the steam enters the soil or to the lower steam discharge rate from the pipe. To determine which of these factors was responsible, the orifices in one set of pipes were doubled in number, i.e. orifices were spaced at $2\frac{1}{2}$ in. instead of the standard 5 in. This resulted in lower

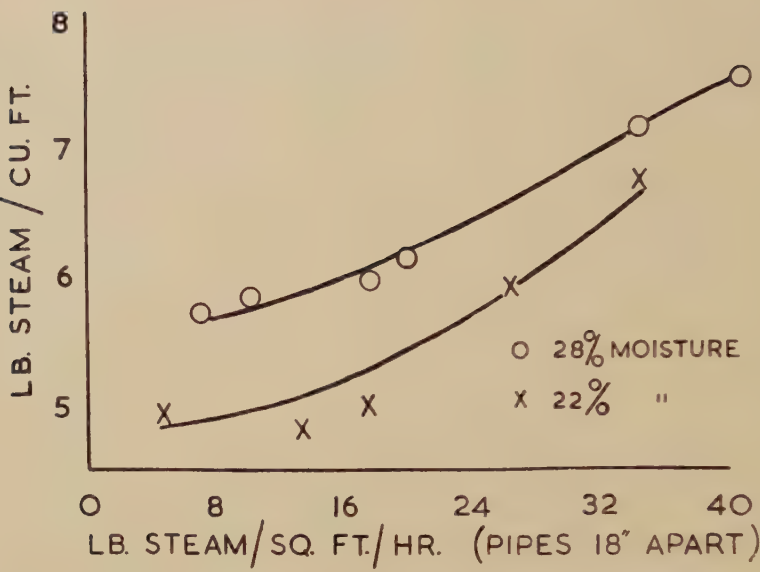

FIG. 3.
Increase in quantity of steam per cubic foot of soil with increasing steam injection rate per square foot.

pressures, but the rate of steam flow at any given boiler pressure was unaltered. The two sets were compared, over a range of steam flow rates, for the amount of steam used per cubic foot of soil. The difference in the means was not statistically significant.

Increase in moisture content.

The increase in soil moisture content of freshly sterilized soil can be attributed to two factors, (1) condensation of part of the steam used to heat the soil, and (2) discharge of free water originating from the carry-over of unvaporized water in the boiler and also from heat losses in the steam main. The observed moisture increase when measured 24 hours after steaming at a depth of 6 in. below the surface, was found to be less than either the equivalent amount of steam used or the calculated minimum steam requirement, especially with dry soils. This is to be expected as

TABLE VII.

Increase in soil moisture content measured at 6 in. depth 24 hours after steaming. The soil covers were removed 20 minutes after steaming had finished.

	Dry soil	Wet soil
Soil initial moisture content	21%	29%
Steam (lb./cu. ft.)	4·5	5·9
Final moisture content	23%	34%
Increase	2%	5%
Equivalent increase in moisture (lb./cu. ft.)	1·0	2·7
Expected increase in soil moisture if heating efficiency 100% and all steam retained in soil	7·8%	10·0%

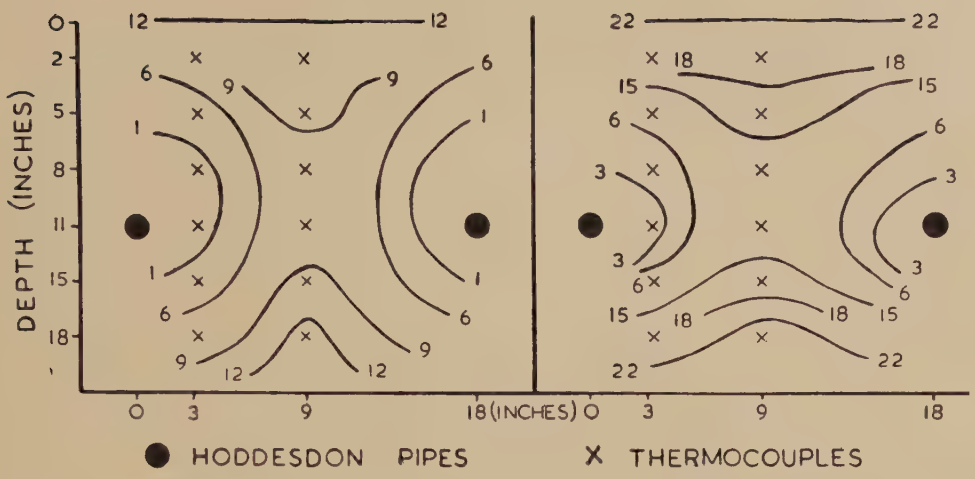

Fig. 4a.
High pressure.

Fig. 4b.
Low pressure.

212° F. isotherms showing typical heating patterns (in minutes) from Hoddesdon pipes with high and low pressure steam.

the heating efficiency is seldom, if ever, 100 per cent. and, in addition, moisture is lost from the soil by evaporation after the steam is turned off. Wet soils require more steam than dry soils and a greater percentage of this steam, in condensed form, is retained by the wet soil due to the reduced pore space and restricted vapour movement. The increase in water content with soils of two moisture contents when steamed with low pressure steam, i.e. as efficiently as possible, is given in Table VII.

It is worth while noting here that a steam drier removes free moisture from the steam more efficiently than the common practice of " cracking " a steam valve at the header. Because of the high steam velocities very little of the free water in the steam is discharged by this method.

Heating and cooling curves.

The pattern of the heating curves with high and low pressure steam was investigated with the aid of thermocouples and a potentiometer ; typical 212° F. isotherms in relation to time are shown in Fig. 4. It will be seen that when the soil below the pipes is forked, the steam penetration at high pressure is slightly greater than at low pressure, the former giving a ridge and furrow type of curve, the latter a more undulating curve. From the pattern of the isotherms in Fig. 4 it would appear that when sterilizing to a depth of 12 in., the pipes should not be spaced farther apart than 18 in. if the risk of strip heating immediately over the pipes is to be avoided. A tendency towards this has been observed at the 18 in. spacing on wet soils that have been steamed at high pressure. The 212° F. isotherms show that a heat front spreads outwards from each pipe. The cold soil is immediately raised from its initial temperature to 212° F. when the steam reaches it and the latent heat is released. There are no intermediate points between these two temperatures. Below the pipes the heat front does not spread so rapidly. At depths of more than 3 in. below the pipes temperatures intermediate between the initial and final soil temperatures were obtained. When the heating period was prolonged, both the intermediate and final

heat fronts spread progressively downwards. After the steam was turned off, the soil immediately under the pipes dropped several degrees in temperature whilst, at greater depths, the soil continued to warm slowly.

It is of interest to compare the soil heating pattern when using Hoddesdon pipes with that of tile drains. Senner's (1934) results show that at 10 in. below the surface the soil temperature rose uniformly over the course of one hour from 80° F. to 212° F., whilst at the surface the same rise in temperature took two hours. The steam rate of injection for this experiment was about 3.5 lb./hr./sq. ft. soil. Increasing the steam injection rate to approximately 10 lb./hr./sq. ft. soil resulted in the heating period for the soil at 10 in. being reduced to 10 minutes, and that for the surface soil to 30 minutes.

Using a steam-air mixture to give a final soil temperature of 180° F. in place of 212° F. the author (unpublished work) has found that, during heating, three distinct soil temperatures are obtained. First an inner area adjoining the pipes at 180° F., next a soil layer at a temperature intermediate between that of the heated and unheated soil, and lastly the remaining soil still at the initial temperature.

In actual practice, cold spots or unevenness in heating at the surface, caused by differences in soil compaction, frequently occur and, unless careful watch is kept, the steam is turned off before these spots have been heated. To determine whether heat would spread upwards sufficiently to sterilize this cold soil, a plot with an initial moisture content of 29 per cent. was first thoroughly steamed. A 2 in. layer of cold soil having a fine tilth similar to soil passed through a $\frac{3}{8}$ in. riddle, was next spread on the top. Thermocouples were inserted at $\frac{1}{4}$ in. and 1 in. depths in this cold layer and half of the cold soil was then covered with four thicknesses of hessian, the

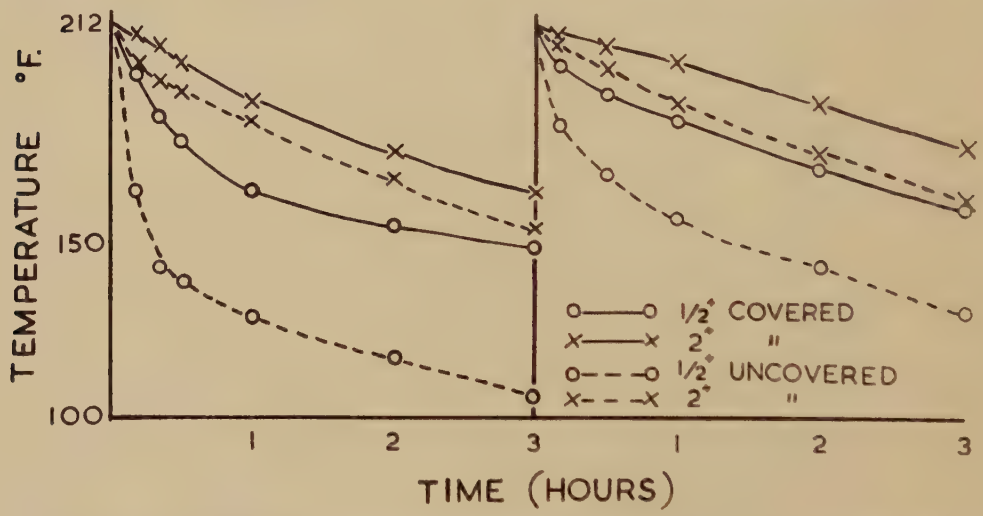

FIG. 5A. FIG. 5B.

Cooling rates of covered and uncovered soil at $\frac{1}{2}$ in. and 2 in. depth under low and high solar radiation conditions.

	Fig. 5A.	Fig. 5B.
Outside screen temperature	52° F.	64° F.
Glasshouse temperature	58° F.	75° F.
Sun hours during experiment	0·0	2·7
Total sun hours for day	0·7	6·5

remaining half left uncovered. After 2½ hours the temperature below the covers at ¼ in. depth had risen progressively to 160° F., the minimum sterilizing temperature, whilst the temperature of the uncovered soil at the same depth was 108° F. This was repeated with a drier soil, having 19 per cent. moisture content. The maximum temperature reached with this soil at the ¼ in. depth under the covers was 140° F. after 4 hours ; the uncovered soil at the same depth was 98° F.

The isotherms of the 10-minute " trickle finish " were examined and, as was expected, the soil at pipe level and above remained at 212° F. during the 10-minute period. At 3 in. below the pipe, the temperature had fallen 15° F., whilst at 6 in. it had risen 10–15° F., showing that there was no further penetration of steam at the low flow rate.

Sterilized soil loses heat by conduction to the subsoil and by radiation and evaporation from the surface. The effect of leaving freshly sterilized soil covered with four layers of hessian instead of moving the covers immediately after the " cook " as is normally done, is shown in Fig. 5. Under low solar radiation (cloudy) conditions the hessian cover had a marked insulating effect on the cooling rate of the top two inches of soil. After 3 hours the soil at ½ in. below the covers was 40° F. warmer than the uncovered soil. No significant difference was found under these conditions between the cooling rates of soils with 19 per cent. and 29 per cent. moisture. Under higher solar radiation (sunny) conditions the difference in the cooling rate between covered and uncovered soil was not as great.

DISCUSSION.

The results presented in this paper show that under practical conditions, the thermal efficiency of steam sterilization varies inversely with the rate of steam injection into the soil. It is important to note that it is the *rate** per unit area of soil which is the determining factor and not the pressure. Thus, on the basis of these experiments, the maximum thermal efficiency is obtained when the rate does not exceed 18 lb. of steam per hour per square foot of soil surface. This is equivalent to a discharge rate of approximately 3·1 lb. of steam per minute per 7 ft. pipe, or a pressure of 2 lb. per sq. in. in the standard Hoddesdon pipe, with the latter spaced at 18 in.

The conclusions to be drawn from these experiments on soil sterilization *in situ*, are at variance with those arrived at by the author for soil sterilization in bins (Bunt, 1954). In bins, the quantity of steam used per cubic foot of soil increased as the steam injection rate was decreased. This increase, however, was accounted for by the continuous loss of steam from the ends of the bin, a loss which cannot occur with *in situ* sterilizing.

A low rate of steam injection can be achieved in a number of ways. Gamble (1948) and Morris (1952) recommend the use of a pressure-reducing valve close to the header. This operates by restricting the flow of steam to the Hoddesdon pipes. A simpler method has been to balance the full boiler output against the area being steamed. For example, to ensure the correct rate of 18 lb. steam/hr./sq. ft., a boiler producing 1,500 lb. steam per hour must supply a soil area of 84 sq. ft., equivalent to 8 pipes each 7 ft. long, or 4 pipes each 14 ft. long, spaced at 18 in. apart. It is

* Because of the widespread confusion derived from the terms " low pressure " and " high pressure ", it is proposed to replace them with the more explicit terms " low rate " and " high rate ".

proposed to call this method " balanced steaming ". By this procedure, a low steaming rate is automatically ensured irrespective of the boiler pressure.

Using low rate steaming, a longer time is required to reach sterilizing temperature. If, therefore, low rate steaming is adopted without increasing the unit working area, only a part of the potential boiler output will be used and it will then be found that the additional labour cost incurred would more than outweigh the saving in fuel from the low rate but unbalanced steaming.

The economic importance of balanced steaming is emphasized if we consider the following examples. Under conditions prevailing in the 1953 experiment, Table VI, unbalanced low rate steaming would incur an extra £90 per acre for labour, whereas balanced steaming would give a saving of £16 per acre in fuel with no extra labour costs. With conditions similar to those in the 1951 experiment, Table V, the saving in fuel at the unbalanced low rate would equal the additional labour costs, whereas balanced steaming would give a fuel saving of £54 per acre with no extra labour costs.

It may be found that, without a reducing valve, pressure at the header will not remain constant. Fig. 2 shows that pressure both at the header and at the boiler is determined by the rate of steam flow, a fall in header pressure indicating a lower rate of flow. This would be caused by either erratic firing or by water being taken into the boiler. Such a fall in header pressure is of no consequence, since the full amount of steam produced is being used at maximum thermal efficiency. It is only a rise in header pressure, caused by an increased steam flow, which leads to inefficiency. Variations in the rate of steam production from low pressure boilers can be just as great as from high pressure boilers. But, because of the much larger diameter of the mains used with low pressure boilers, the pressure fluctuations are smaller.

The boiler evaporation rate can be held steady by leaving a small water injector running continuously, instead of using a large injector periodically, and by frequent attention to the fire.

It is customary to cover the soil, during sterilizing, with tarpaulins to reduce the loss of uncondensed steam. Observations during these experiments show that this method is not efficient, especially when steam is used at a high rate. An inverted, metal tray should prove more efficient. Spoelstra (1951) has recommended a 1 in. layer of granulated peat to prevent the escape of steam from the soil surface and to conserve heat. Simpson and Newton (1949) found that in an autoclave, operating at 15 lb./sq. in., it required 50 minutes for the heat to penetrate to a depth of 1 in. in air-dry peat, but when the moisture content of the peat was increased to 50 per cent. of its capacity, the heating period was reduced to 20 minutes.

During the course of these experiments the quick-acting types of irrigation couplings have been found to be quicker and quite satisfactory for connecting the Hoddesdon pipes to the steam header hoses.

Although Hoddesdon pipes only have been used throughout these experiments, the conclusion reached regarding the optimal rate of steam injection most probably applies to other methods of *in situ* sterilizing.

SUMMARY.

1. A study has been made of the effects of high and low steam pressure in the sterilization *in situ* of glasshouse soils.

2. Thermal efficiency depends on the rate of steam injection (lb.) per unit volume of soil and not on the pressure at which the steam is injected.

3. It was found that the maximum rate should not exceed 18 lb. of steam per hour per sq. ft. of soil surface, equivalent to (*a*) 3·1 lb. (weight) per minute, or (*b*) 2 lb. (pressure)/sq. in. per standard Hoddesdon pipe, with the latter spaced at 18 in.

4. The saving from low rate steaming ranged from 1·0 to 3·5 lb. per cu. ft. of soil, the amount depending on the heat requirement of the soil and the contrasts in rates used.

5. The steam flow rates and pressure losses for a 2 in. steam system are given.

6. A method termed " balanced steaming " is described which combines high thermal efficiency with maximum working rate.

ACKNOWLEDGMENTS.

The author gratefully acknowledges the loan of steam meters by the Ministry of Fuel and Power, Eastern Region, and the National Institute of Agricultural Engineering, Silsoe, Beds. ; also, the mechanical analysis of the glasshouse soil by the Rothamsted Experimental Station.

REFERENCES.

Bunt, A. C. (1954). Steam pressure in soil sterilization. I. In bins. J. hort. Sci., **29,** 89-97.

Enkel, F. G. (1948). Soil sterilization in Essex. Paper read at the conference on sterilization of glasshouse soil, Institute of Agriculture, St. Albans, Herts, 1/6/48.

Fawcett, C. H. (1949). Glasshouse heating with low pressure steam. The Grower **31,** 498-501, 551-5.

Gamble, W. H. (1948). Steam sterilization of soil. Paper read at the conference on sterilization of glasshouse soil, Institute of Agriculture, St. Albans, Herts. 1/6/48.

Lyle, O. (1947). The efficient use of steam. H.M. Stationery Office.

Ministry of Agriculture and Fisheries (1947). Bulletin No. 22. Practical soil sterilization.

Morris, L. G. (1952). The steam sterilization of soil. C.S. 14/1170, National Institute of Agricultural Engineering.

Roll-Hansen, J. (1949). Damping av jord. A/L Norsk. Gartnerforenings Forlag.

Senner, A. H. (1934). Application of steam in the sterilization of soils. Technical Bulletin No. 443, U.S.D.A.

Simpson, F. J., and *Newton, J. D.* (1949). Studies on steam sterilization of soils. II. Some factors affecting minimum requirements. Canadian Journal of Research, C. **27** : 1-13.

Spoelstra, P. A. (1951). Grondstomen. Med. Dir. Tuinbouw, **14,** 566-75.

(*Received* 26/3/54.)

STRAWBERRY YELLOWS IN THE VARIETY AUCHINCRUIVE CLIMAX

By A. F. POSNETTE and R. CROPLEY
East Malling Research Station, Kent

In the spring of 1950 an abnormal yellowing of the young leaves of Auchincruive Climax plants occurred in several strawberry fields in Britain. The yellowing became more widespread in each subsequent year until, in 1953, it was a common feature of runner beds and young fruiting plantations of this variety throughout the country. Reid (1951) suggested that the condition was similar to "June Yellows", which has long been prevalent in several North American varieties, Blakemore in particular (Demaree, 1948). When grown together in a glasshouse at East Malling, Climax and Blakemore developed the same type of yellows simultaneously.

Two distinct abnormalities, here called "transient yellows" and "streak", are now prevalent on Climax; we have not found that either is infectious. Although Royal Sovereign has occasionally been reported to show transient yellows and streak, and seedlings of the East Malling clonal *Fragaria vesca* sometimes develop streak, these varieties have not been affected by grafting to Climax plants with yellows and streak. Transmission tests by grafting affected Climax to normal Climax plants have been invalidated by the appearance of yellows and streak on the controls (ungrafted plants), and further tests of this type seem useless because Climax plants develop transient yellows and streak apparently spontaneously in our insect proof glasshouses, and we now have no sub-clones entirely free from these defects.

There is little doubt that transient yellows and streak in Climax are inherited defects, probably controlled by plasmagenes. These abnormalities are not rare in strawberries; seedlings commonly develop symptoms in their first or second year and are then discarded by the breeder, and the writers have observed streak in the varieties Perle de Prague, Mme. Lefebvre, Mme. Kooi (Moutot) and Cambridge Favourite. The appearance of these defects after Climax had become a dominant variety in Britain is a serious misfortune.

Description of symptoms.

Transient yellows.

Young leaves developing during April, May, and sometimes in early June, are bright yellow, occasionally over the whole lamina but usually there are clearly defined yellow and green sectors (Fig. 1). The symptoms disappear during late May and June, probably because of rising temperatures, as they also disappear rapidly when affected plants are brought into a heated glasshouse. Symptoms frequently reappear in the autumn, particularly in runner-beds, where the yellowing is most common and pronounced on the youngest runners.

Streak.

In addition to transient yellows, the leaves of Auchincruive Climax plants are sometimes variegated, usually with white streaks. When only a few white flecks are

Table I.

The history of four sub-clones (strains) of Auchincruive Climax.

1945
Plant from W. of Scotland Agricultural College
(Tested and found virus-free)

1946
Propagation in insect-proof house

1947–50
Each year 1 runner rooted into a pot in an insect-proof glasshouse; the young runner retained and parent discarded.

1951
Unlimited runner-production in propagation bed in an insect-proof glasshouse. No yellows symptoms up to and including autumn, 1951.
Strain 1.

1947–50. Stock maintained by unlimited runnering in an insect-proof gauze house.

1951
Unlimited runner-production from 1 plant in an isolated outdoor runner bed. No yellows symptoms up to and including autumn, 1951.
Strain 2.

1951
Unlimited runner-production from 1 plant in propagation bed in an insect-proof glasshouse. No yellows symptoms up to and including autumn, 1951.
Strain 3.

1951
Unlimited runner-production from 1 plant in an isolated outdoor runner-bed. Transient yellows symptoms in autumn, 1951.
Strain 4.

present the leaves retain their normal shape, but when streaking is severe they often become deeply serrated, puckered and distorted (Fig. 2). The lower surface of streaked leaves is mottled with dark and light green areas delimited by the veins. Severely affected plants have a grey-green appearance, and resemble plants severely infested with the Greenhouse Red Spider Mite. Streak usually appears first on leaves expanding in the spring, and symptoms persist as white or grey-brown streaks until the leaves die. Only very occasionally have white streaks been seen on leaves which

emerge during the late summer and autumn. The young expanding leaves on streak plants are frequently pink or red in early spring, particularly during cold weather.

Comparison of four sub-clones of Auchincruive Climax.

Field observations suggested that Climax stocks from various sources differed greatly in the incidence of yellows and streak. A field trial was started in 1951 to determine whether this difference was permanent or due primarily to local environment. The history of the material used in this trial is given in Table I, from which it can be seen that all the sub-clones (hereafter called strains) were derived from one plant, but that Strain 1 differed from Strains 2, 3 and 4 in that it had been maintained for four years without intensive propagation. Strains 1 and 3 were virus-free at planting time, having been tested in 1951 during their propagation in an insect-proof glasshouse. Strains 2 and 4 had been propagated out of doors in 1951 but they were grown in an isolated runner-bed which was regularly sprayed against aphids, thus keeping them also probably virus-free.

Experimental design.

Twenty plants of each strain were potted in November, 1951, and wintered in an insect-proof glasshouse. The plants were planted in the field on 21st March, 1952, in rows 6 ft. apart with 2 ft. between the plants in the row. Five plants of a strain formed one plot, and four plots one block, with four replications.

Observations during 1952.

The plants were deblossomed during 1952, and runners allowed to grow and root after mid-August ; these runners were removed in November. Records were made of transient yellows and streak symptoms during April, May, September and October (Table II), symptoms on the parent plants and on the young runners being recorded separately in the autumn. Strain 1 showed no symptoms throughout the year. Most of the plants of Strains 2 and 3 developed transient yellows in the spring, and

Table II.

Classification of plants according to yellows symptoms in 1952 and 1953.

		Strain 1		Strain 2		Strain 3		Strain 4	
		Parent	Runner	Parent	Runner	Parent	Runner	Parent	Runner
Spring, 1952	N	20		8		2		0	
	TY	0		12		16		5	
	TY+S	0		0		2		15	
Autumn, 1952	N	20	20	18	3	18	0	7	0
	TY	0	0	2	17	2	20	13	20
Spring, 1953	N	4		0		0		0	
	TY	12		3		0		0	
	TY+S	4		17		20		20	
Autumn, 1953	N	15	3	8	0	4	0	5	0
	TY	5	17	12	20	16	20	15	19

N=Normal ; TY=Transient Yellows ; TY+S=Transient Yellows and Streak.

again in the autumn on the young runners. Most of Strain 4 showed symptoms of transient yellows and streak in the spring, and of transient yellows again in the autumn on the young runners and the parent plants. The transient symptoms on Strain 4 were a much brighter yellow than those on Strains 2 and 3.

Observations during 1953.

The parent plants were allowed to fruit during 1953, and runners were again allowed to grow after mid-August. Transient yellows and streak symptoms were recorded during April, May, June and October (Table II). In the autumn, streak was usually still visible on spring-formed leaves, but it was recorded on only one autumn-formed leaf. Some plants of Strain 1 developed mild symptoms of transient yellows, and four plants also showed very mild streak. Most of the plants of Strain 2 and all of Strains 3 and 4 showed transient yellows and streak ; the symptoms on Strain 4 were the most severe, with rugose, distorted leaves.

Table III.

Differences in vigour and cropping capacity of two-year-old plants of four strains of Auchincruive Climax.

Summer, 1953	Strain 1	Strain 2	Strain 3	Strain 4	Sig. diff. P=0·05
Crop weight. Mean weight (lb.) per plot of 5 plants	3·22	1·87	1·60	0·9	0·9
Fruit size. Weight (lb.) of 100 ungraded fruits	1·20	0·79	0·66	0·43	0·26
Surface area of plants. Sum for 5 plants in sq. in.	1464·8	1094·1	892·2	804·2	266·2
Leaf size. Area in sq. millimetres of one leaflet	3865	2496	2250	1650	389

Means bracketed together do not differ significantly.

Effect on plant size. Each plant was measured in May, 1953, and its surface area calculated (Table III). The plants of Strain 1, in which no yellows developed until the spring of 1953, were much larger than those of the other three strains, in each of which some plants had shown yellows in the spring of 1952. The plants of Strain 4, which had shown yellows in the autumn of 1951 and streak in 1952 and 1953, were the least vigorous and little more than half the size of the " normal " plants of Strain 1 (Fig. 3).

Leaf area was also measured (sample of 6 leaflets per plant). Leaves of Strain 1 were found to be over twice the size of those of Strain 4, with Strains 2 and 3 intermediate.

Effect on fruit. The trial was not intended to assess the effect of yellows on cropping, but as unexpectedly large differences developed in plant size, the number and weight of fruit produced by each strain were recorded in 1953 (Table III). The

differences in cropping are probably due to transient yellows and streak, as the strains were comparable in other respects. *Note added in proof:* In 1954, the relative crops of the four strains were similar to those in 1953, the only significant change being a reduction in the crop of Strain 3. Besides the difference in fruit size noted in both years, the number of fruits produced by Strain 1 was significantly greater than that produced by Strains 3 and 4 in 1954. Most berries on the stunted plants ripened to a dull red colour in contrast with the bright red fruit on the vigorous Strain 1 plants.

DISCUSSION.

The case histories of the four strains, as summarized in Table II, support general observations in the field that plants which show transient yellows in the autumn will develop streak in the following spring. Autumn yellows developed more frequently on the runners than on the parent plant ; had runners been removed in the summer, no yellows would have been recorded on many of the plants that developed streak in the following spring. Some plants showed yellows and slight streak in the spring with no previous record of yellows, as, for example, did four plants of Strain 1 in 1953. It appears, therefore, that roguing plants with yellows cannot be expected to eliminate streak completely. The history of Strain 1 suggests that once a clone has developed transient yellows, the onset of streak will not be long delayed. Although Strain 1 was completely normal throughout 1952, 16 of the 20 plants showed yellows in the spring of 1953, four of them also with streak ; from the appearance of transient yellows in the autumn, it can be forecast that all but three plants will develop streak in 1954. *Note added in proof:* All plants in the experiment showed streak in the spring of 1954 but Strain 1 plants had milder symptoms than those of other strains.

A comparison of Tables II and III shows that vigour and cropping are inversely proportional to the degree of streak, if " degree " includes not only the number of affected plants but also the time that they have been affected. For instance, when Strain 2 was producing twice the crop of Strain 4 in 1953, there was little difference in the number of plants with streak but, in the spring of 1952, 15 plants of Strain 4 had shown streak, compared with none of Strain 2.

Owing to the unpredictable behaviour of the strains of Auchincruive Climax used in this experiment, it has not been possible to assess accurately the effect of transient yellows alone on vigour and cropping. Most of the plants of Strain 1, which was intended to be the " normal " standard, developed transient yellows in 1953, when most of the plants of Strains 2 and 3 also developed streak. There is evidence to suggest, however, that mild transient yellows without streak does reduce the vigour of plants. Considering Strain 1, the four plants which were still normal in the spring of 1953 had a mean surface area of 375·8 sq. in., compared with 258·4 sq. in. for the twelve plants which developed transient yellows in the spring of 1953. (This difference is significant at the 5 per cent. level.) It is not possible to compare the crop records of these individual plants, since the fruit was recorded not from each plant, but from each plot of five plants.

There is considerable circumstantial evidence that the development of transient yellows and streak in Climax is accelerated by rapid runner production. Most of the plantations which are still free from yellows were planted three or four years ago ; these plants have probably been subjected to less propagation that later-planted beds. Between 1947 and 1950 the best strain (1) used in this experiment had not been

PLATE I.

Fig. 1.
Leaflets of Auchincruive Climax showing transient yellows. Normal leaflet on left.

Fig. 2.
Leaf of Auchincruive Climax showing streak.

[face p. 60

PLATE II.

FIG. 3.

Two plants of Auchincruive Climax planted in March, 1952. The plant on the right first showed yellows in October, 1952, and streak in May, 1953. The plant on the left first showed transient yellows in May, 1953, and streak in May, 1954. Photographed June, 1954.

subjected to the rapid propagation methods which were used to maintain Strains 2, 3 and 4 (see Table I). During 1952, however, plants of Strain 1 were propagated in runner-beds at East Malling and elsewhere, and transient yellows symptoms were recorded on the runners of several plants in the autumn of 1952 ; in 1953, many of these runners were severely affected with streak. This contrasts with the behaviour of the fruiting plants which were not subjected to rapid propagation in this experiment.

If the hypothesis is accepted that the development of yellows is accelerated by intensive runner-production, it is clear that although many normal plants exist, they are unlikely to withstand the rapid propagation necessary to distribute new clones to the industry. In fact, three clones raised from old fruiting plants, which had been free from yellows up to 1952, have shown yellows in 1954. If it had been possible to predict this degeneration of Auchincruive Climax, it seems probable that the general onset of yellows could have been postponed for many years by preserving a stock of healthy plants at an early stage in the life of the variety, maintaining them by crown division only and then using them successively as each strain in turn developed yellows after several years of intensive propagation. This procedure is commended for any future varieties which may be introduced with a history of yellows in their ancestry.

SUMMARY.

The characteristics of transient yellows and streak of Auchincruive Climax are described. These abnormalities are regarded as genetical ; there is evidence that they are not graft-transmissible, and they seem to occur spontaneously in insect-proof glasshouses.

The development of transient yellows and streak in four sub-clones (strains) of Auchincruive Climax is described. Yellows developed a year later in the strain which had not been propagated intensively than in those which had undergone unlimited runner production for five years.

Transient yellows in the autumn was invariably followed by streak in the following spring ; streak sometimes developed on plants which had not previously shown transient yellows.

Vigour and cropping were greatly reduced by streak. There was evidence that transient yellows alone reduced vigour, but no data were available regarding its effect on crop.

ACKNOWLEDGMENTS.

The authors are indebted to Mr. G. H. Freeman for the statistical analyses, and to Mr. E. Yoxall Jones for the photographs.

REFERENCES.

Demaree, J. B. (1948). Diseases of strawberries. U.S.D.A. Farmers' Bull. No. 1891.

Reid, R. D. (1951). June Yellows in Auchincruive Climax strawberries. Grower, **35,** 1160.

(*Received* 25/3/54.)

STUDIES IN THE DEVELOPMENT OF THE STRAWBERRY

III. FLOWER-BUD INITIATION AND DEVELOPMENT IN LARGE-FRUITED PERPETUAL ("REMONTANT") STRAWBERRIES

By MARGARET ROBERTSON

Scottish Horticultural Research Institute, Mylnefield, Invergowrie, By Dundee

In recent years British growers have shown an increased interest in strawberry varieties of the large-fruited perpetual (" remontant ") type, most of which are of French or American origin. Much has been written concerning their cultivation and cropping (Henderson, 1952 ; Hyams, 1952a, 1952b, 1953 ; Cumberland, 1953) but, except for the work of Waldo (1930, 1935) in America, few details are known of their annual cycle of bud development. This paper describes observations on flower-bud formation in three of a collection of these strawberries grown in the open at Mylnefield, and compares their behaviour with that of Royal Sovereign and Auchincruive Climax. A fourth variety received for the collection was confirmed to be of the ordinary spring-flowering type.

Materials and methods.

First-year plants of the varieties Inépuisable, Perle Rose, Libération d'Orléans and Ville de Paris, planted in mid-April, 1952, and deblossomed until the end of May, were allowed to form runners on a maximum of six primary stolons per plant. As in previous work (Robertson and Wood, 1954) the runners were labelled weekly, according to their approximate dates of formation, and samples were examined at intervals by dissection. The condition of the anthers of the terminal flower was used as a measure of inflorescence development, based on the following arbitrary stages :

0=anther initials not recognizable ;
1=initials visible ;
2=initials small, rectangular ;
3=anthers small, slightly lobed ;
4=anthers large, distinctly lobed ;
*7=pollen present ; inflorescence at " green-bud " stage.

The terminology here used is the same as in the previous papers of this series.

Observations.

1. *Inépuisable.*

This variety grew poorly in 1952, and by 15th August the four mother plants had formed only 17 runners, of which 7 were flowering. The mother plants themselves developed more flowers after being deblossomed : six inflorescences had emerged by 24th July and twelve by 15th August. In 1953 both first and second year

* Stages 5 and 6 (Robertson and Wood, 1954) were omitted when examining by dissection.

plants flowered in May and again from mid-July until mid-October, when frost occurred. Details of runners examined are given in Table I.

Flower initiation in 1952 probably occurred from late May or early June until late August. Early-formed runners generally developed two " main " inflorescences (those successively terminal on the growing crown), one or both of which flowered in late summer, whilst some August-formed runners remained vegetative. Inflorescences that did not emerge in 1952 developed during the following spring to produce the first crop of flowers in 1953, opening towards mid-May. Some 2–4 weeks later the plants were forming the primordia of the flowers that were to open from July onwards. This sequence of events is illustrated in Fig. 1. Few " axillary " inflorescences (Robertson and Wood, 1954) were formed in this variety, and none were seen to flower.

TABLE I.

Development of inflorescences in variety Inépuisable.

Date examined	Date of runner plant	Number of main inflorescences	*Stages observed
18/8/52	*1952 runners*		
	mid-June	2	Fl. ; 1–2
	23/7	0	
	6/8	0	
29/10/52	23/7	1	7
	6/8	0	
	6/8	4	Fr. ; Fl. ; Fl. ; 3–4
	20/8	0	
	early Sept.	0	
18/2/53	late June	2	Fld. in 1952 ; 3
	30/7	1	2–3
	30/7	0	
9/4/53	20/8	1	7
	20/8	0	
	27/8	1	7
18/6/53	30/7	2	1–2 ; 0
10/9/53	*1953 runners*†		
	1	1	0
	2, 3, 4	0	

* This column gives the condition of the inflorescences in order of age :
0=anther initials not recognizable.
1=initials visible.
2=initials small, rectangular.
3=anthers small, slightly lobed.
4=anthers large, distinctly lobed.
7=pollen present, green-bud stage.
Fr.=fruiting ; Fld.=flowered ; Fl.=flowering.

† Undated, but numbered in order of age :
1=oldest ; 4=youngest.

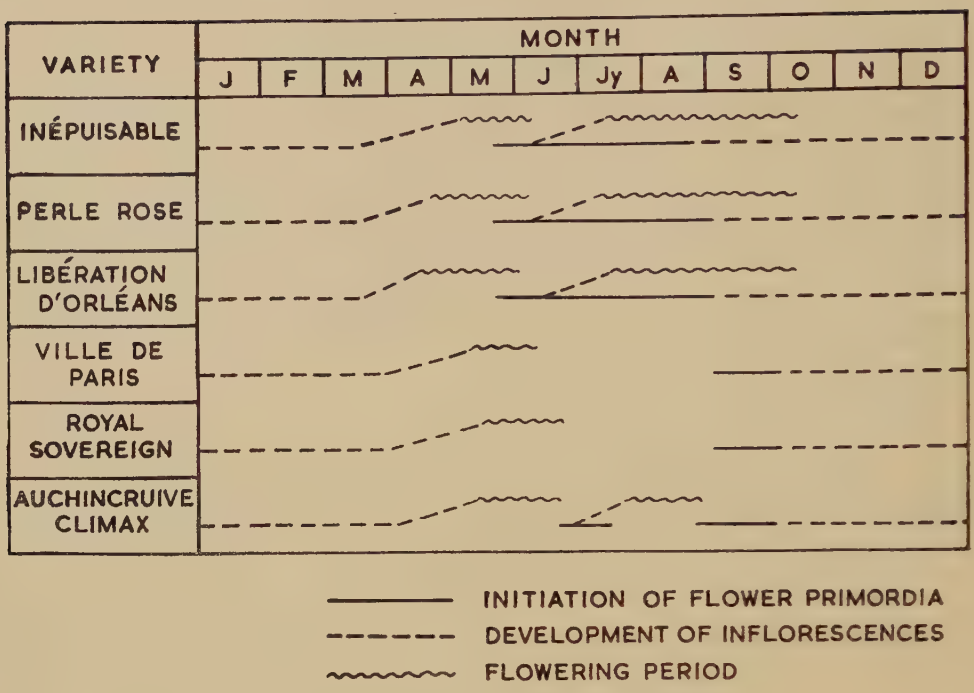

Fig. 1.

Comparative periods of flower initiation, inflorescence development and flowering, in six strawberry varieties. (N.B. The precise time when flower initiation in such varieties as Royal Sovereign ceases in autumn is uncertain, but the main period of initiation is as shown.)

2. *Perle Rose.*

By 15th August, 1952, the four mother plants of Perle Rose had formed 66 runners, 9 of which were flowering. The individual plants were small. The deblossomed mother plants produced a further 24 inflorescences by 24th July and 40 by 15th August. In 1953, first and second year plants flowered from late April until early June and again from mid-July until checked by the October frost. Table II gives details of the runners examined.

The data indicate that flower initiation occurred continuously from late May or early June until early or mid-September. Early runners generally developed 3 or 4 main inflorescences, but August and September runners not more than one. The first (and sometimes second) order inflorescences of early runners generally flowered in late summer, and some inflorescences of runners were frosted in autumn at the green-bud stage. In general, the cycle of flower-bud initiation and development resembled that of Inépuisable (Fig. 1) ; but most of the early-formed runners in 1952 developed axillary inflorescences, several of which flowered in the following spring.

3. *Libération d'Orléans.*

By 15th August, 1952, the six mother plants of this variety had formed 65 runners, 12 of which were flowering. The deblossomed mother plants produced

TABLE II.

Development of inflorescences in variety Perle Rose.

Date examined	Date of runner plant		Number of main inflorescences	*Stages observed
	1952 runners			
13/8/52	early June		3	Fr. ; 7 ; 2
	30/7		1	7
	30/7		1	1
29/10/52	early June		4	Fr. ; Fl. ; 3–4 ; 1
	10/7		3	Fl. ; 3–4 ; 1–2
	30/7		3	3–4 ; 2–3 ; 0–1
	6/8		1	1–2
	20/8		1	1–2
	early Sept.		1	1
	late Sept.		0	
18/2/53	mid-June		4	Fld. in 1952 ; ditto ; 7 ; 2–3
	30/7		2	3 ; 0
	13/8		0	
	27/8		1	1
9/4/53	17/7		3	Fld. in 1952 ; 7 ; 7
	30/7		1	7
	13/8		1	7
	27/8		1	7
18/6/53	mid-June	P	5	Fr. ; Fr. ; 3 ; 0–1 ; 0
		S	3	Fr. ; Fr. ; 0–1
	30/7	P	2	Fr. ; Fr.
		S	2	7 ; 1–2
	6/8	P	2	Fr. ; 1–2
		S	2	Fr. ; 2
	1953 runners			
18/6/53	early June		1	0–1
10/9/53	1†		3	Fl. ; 2 ; 0
	2		3	Fr. ; Fl. ; 1
	3		1	0
	4		1	0–1
	5		1	0–1

*, †—see Table I. P, S = Primary and Secondary (branch) crowns.

7 more inflorescences by 24th July and 16 by 15th August. Flowering in 1953 began in mid-April, continued throughout May, and was resumed from late July until mid-October. Details of runners examined are given in Table III.

Flower initiation and development occurred at much the same times as in Perle Rose (Fig. 1). Most early runners formed 2 or 3 main inflorescences, one of which usually flowered in late summer. The remainder continued to develop during autumn, and many were injured by frost in the winter when at green-bud stage. As in Perle Rose, several axillary inflorescences were formed in early runners. None flowered in the current season, but a few did so in the following spring.

TABLE III.

Development of inflorescences in variety Libération d'Orléans.

Date examined	Date of runner plant	Number of main inflorescences	*Stages observed
	1952 runners		
18/7/52	early June	2	3–4 ; 0–1
	mid-June	1	2
	17/7	0	
18/8/52	mid-June	2	1–2 ; 0
	23/7	2	Fl. ; 0
	6/8	0	
29/10/52	early June	2	Fr. ; 2–3
	mid-June	3	Fr. ; Fl. ; 2–3
	23/7	2	Fl. ; 1–2
	6/8	1	7
	27/8	1	1
18/2/53	late June	2	Fld. in 1952 ; 7
	23/7	2	7 ; 7
	13/8	1	3
	27/8	0	
9/4/53	early June	2	Fld. in 1952 ; 7
	23/7	2	Fld. in 1952 ; 7
18/6/53	17/7	2	3 ; 0
	13/8	2	4 ; 0
	September	2	4 ; 0–1
10/9/53	6/8	P 5	Fr. ; Fr. ; Fl. ; 7 ; 1
		S (i) 2	7 ; 0–1
		S (ii) 2	Fl. ; 0
	1953 runners†		
10/9/53	1	1	1
	2	3	Fr. ; 2 ; 0
	3	2	Fl. ; 0

*, †—see Table I. P, S=Primary and Secondary (branch) crowns.

4. *Ville de Paris.*

Received in a consignment of " remontants ", this variety was later found listed as a spring-flowering strawberry. Its behaviour contrasts with that of the varieties already described.

The six deblossomed mother plants produced no further inflorescences in the summer of 1952, nor did any of their numerous runners flower. Flower primordia were not seen until September, and initiation probably began in the early part of that month (Fig. 1). There was little development during winter, but green-bud stage was general by the fourth week of April, 1953, and flowering took place between early May and early June. Axillary inflorescences were formed but very few emerged.

DISCUSSION.

Large-fruited perpetual strawberries seem generally to have two main periods of flowering, the first from about late April until late May or early June and the second from mid- or late July until frost terminates growth. This has proved true of most varieties in the Mylnefield collection and agrees with published experience elsewhere in Britain, although Hyams (1952b) states that some varieties do flower and fruit fairly continuously. Of the varieties here described, Inépuisable, Perle Rose and Libération d'Orléans behaved as true " remontants ", Inépuisable showing the least flowering of current-season runners. Other experience indicates that Libération d'Orléans may behave inconsistently (Hyams, 1952a). Ville de Paris is not a " remontant ", its cycle of bud development closely resembling that of Royal Sovereign (Fig. 1). The somewhat intermediate behaviour of Auchincruive Climax (Robertson and Wood, 1954) is also shown in Fig. 1.

Flower initiation in " remontants " begins early in the season—probably by the end of May or early June, which is at least 3–4 weeks before the summer initiation in Auchincruive Climax (Guttridge, 1952 ; Robertson and Wood, 1954). It seems to continue with little interruption until late August or early September, so that an autumn examination of early-formed runners reveals series of inflorescences at decreasing stages of development, whilst some late-formed runners may be vegetative. There is no indication (from the varieties examined) of a distinct autumn period of flower initiation as seen in Royal Sovereign or Ville de Paris. The present observations agree with those of Waldo (1930), who found that in American perpetual varieties the spring flowers were initiated in the previous year and the later ones in the current season.

Experience with these varieties at Mylnefield is still brief. Under open field culture, however, several have already proved unsatisfactory in one or more important respects, including the size, texture, colour and flavour of the fruit and their liability to frost injury ; and none have equalled Auchincruive Climax in vigour or commercial fruit quality. Nevertheless, they offer a genuine extension of season ; some must owe their poor performance, in part, to virus infection. (It may be noted that there appears to be no evidence that the virus factor is likely to affect the time of flower initiation.) It is scarcely surprising that strawberry varieties of Continental origin should prove poorly adapted to conditions in northern Britain, and the future here of this type of strawberry, if any, may well be dependent on breeding.

SUMMARY.

1. Initiation and development of flower primordia were studied in the " remontant " strawberry varieties Inépuisable, Perle Rose and Libération d'Orléans, using runners of known age and their mother plants.

2. Flowers appearing from late April until about early June were derived from primordia formed in late summer or early autumn of the previous year. Flowers borne from mid- or late July onwards were initiated a few weeks before emergence.

3. Early-formed runners developed flower primordia at an early stage in their growth, and generally flowered in mid- to late summer with their mother plants.

4. Preliminary observations are made on the performance of " remontant " varieties in the East of Scotland.

ACKNOWLEDGMENTS.

Plants used in this work were very kindly supplied by Mr. R. L. Scarlett, C.B.E., of Musselburgh, by Monsieur Georges Delbard, of Paris and by the late Major Douglas Corner, of Lustleigh, Devon.

REFERENCES.

Cumberland, R. (1953). Cultivating perpetual strawberries. Grower, **40,** 399-401.

Guttridge, C. G. (1952). Inflorescence initiation and aspects of the growth habit of the strawberry. Ann. Rep. Long Ashton Res. Sta. 1951, 42-8.

Henderson, C. W. P. (1952). New autumn-fruiting strawberries. Fruitgrower, 10th January, 1952, No. 2924, 47-9.

Hyams, E. (1952a). Perpetual fruiting strawberries. Fruitgrower, 2nd October, 1952, No. 2962, 595-6.

——— (1952b). Perpetual strawberries. The varieties discussed. Fruitgrower, 6th November, 1952, No. 2967, 839-40.

——— (1953). Strawberry cultivation. Faber & Faber, London.

Robertson, M., and *Wood, C. A.* (1954). Studies in the development of the strawberry. I. Flower-bud initiation and development in early- and late-formed runners in 1951 and 1952. J. hort. Sci., **29,** 104-11.

Waldo, G. F. (1930). Fruit-bud formation in everbearing strawberries. J. agric. Res., **40,** 409-16.

——— (1935). Investigations on runner and fruit production of everbearing strawberries. U.S. Dep. Agric. tech. Bull., 470.

(*Received* 25/2/54.)

BOOK REVIEWS

CIDER APPLE PRODUCTION. Ministry of Agriculture Bulletin No. 104. By B. T. P. Barker. (London : H.M. Stationery Office. 1954. Pp. 64, illus. Price 3s.)

This publication, which is the second edition and long overdue, discusses questions of particular interest and importance to producers of cider apples. As far as the reviewer is aware, the first edition, published in 1937, has been unobtainable since about 1940. In the meantime, the production of cider apples has altered materially and Professor Barker is particularly well qualified to describe these important changes.

Throughout the country the cider apple-growing community, mostly farmers, has always been confronted with apparently insuperable difficulties, and the more scientific and practical advice forthcoming the better. This bulletin is useful, not only to the practical grower and cider maker, but also to agricultural and horticultural advisers.

What must impress the reader, especially in comparison with the first edition, is the meticulous care with which the author deals with the newest information on soil management, manuring and the control of pests and diseases and his fine presentation of varietal characters of cider apples. What little information there is on pollination, and on the bush tree plantation as an alternative to the standard tree orchard is given.

Looking at our old cider orchards one feels that most of them would benefit from many of the practices here described, while the production of abundant supplies of good vintage varieties would satisfy growers and cider makers alike. For these two very sufficient reasons all the interests concerned should make the best use of the accumulated knowledge which has been acquired through both practice and science, much of which is covered by the bulletin. Prior to and during World War II, many farmers took more interest in their cider orchards, but the phase is passing, as it has frequently done in the past. One feels that Professor Barker had this in mind in his preface when he wrote that the existing situation as regards supplies of fruit affords an opportunity to press on with the re-organization of the cider industry.

Under existing conditions the factories' task is made unnecessarily difficult by the miscellaneous character of the consignments sent in. This is a direct result of the multiplicity of varieties, which in their turn contribute towards our very low yields ; thus, by planting and grafting with varieties of proved merit, growers' yields and profits would improve and the factories' requirements be better met. Too strong a claim cannot be made out for judicious manuring, especially the correction of nitrogen deficiency, as the normal grazing systems fall very short in the maintenance of fruitful grass orchards, or for varieties with the greatest resistance to insect and fungous attack, especially canker. Growers need to be told more of the economic merits of these varieties.

As their main problem is the extent to which expenditure can be economically related to crop value and orchard welfare, growers would be well advised to take guidance from the information contained in this bulletin. C.S.

THE ENCYCLOPAEDIA OF GARDEN WORK AND TERMS. By A. G. L. Hellyer. (London : Collingridge. 1954. Pp. 288, illus. Price 21s.)

This encyclopaedia has been published to explain to the inexperienced gardener the terms in Sanders' Encyclopaedia of Gardening in particular and the contemporary horticultural language in general. According to its complexity and an experienced author's estimate of its importance to his readers, each word has been defined in from twenty to five thousand or more words. Latin names have been omitted. A judicious balance has been struck between over-woolly and a confusing plethora of detail, but the information could be given much more succinctly and logically. Explanations derive from the standard dogma. The ground has been adequately covered and, with a little casting around, an enquiring beginner, or even a professional, could get some information on most of the words he might expect to be included in this book. A classified bibliography would be a useful addition. Some of the entries are illustrated ; the illustrations, though clear, naturally also depict extraneous objects and would often be improved by such aids to intelligibility as lettering of relevant objects and longer captions.

No serious mistakes were noted, but there is quite a sprinkling of half errors, such as " *chromosome*—the rod-like bodies found in all living cells and containing the numerous genes which control the development of the plant ". Pomologists will appreciate the understatement in " *Regulation* [sic] *pruning* . . . the only skill the gardener has to exercise is that of deciding which of any two shoots is to be removed . . . " and we are assured of the soundness of the author's views by " *Botany* . . . there are two main divisions, Plant Physiology . . . and Taxonomy . . . ".

Provided near-perfection is not required, this book well fulfils its purpose and may be recommended to its specified clientele. D.H.M.

PROCEEDINGS OF THE BRITISH WEED CONTROL CONFERENCE 1953. (London : H.M. Stationery Office. 1954. Pp. 484, illus. Price 30s. to non-members ; from The Secretary, Association of British Insecticide Manufacturers, Cecil Chambers, 86 Strand, London, W.C.2.)

This conference, held at Margate in November, 1953, was organized by the Weed Control Joint Committee on which are represented the various bodies concerned with weed control. The Proceedings, issued with commendable promptitude, contain the full text of all papers read at the conference, together with that of the vigorous discussions which they provoked. Following the opening address of Sir James A. Scott Watson, the losses due to weeds and the potential value of herbicides are assessed by authorities in the different branches of agriculture, horticulture and forestry. Results of experimental work are then described in more than thirty research reports.

A major portion of the Proceedings is devoted to the synthetic growth-regulating substances MCPA and 2,4-D. One group of papers deals with their use on cereals, particularly the effect of treatment at different stages of development on yield and on production of abnormal ears. Several contributors report investigations with these chemicals on seedling grasses and legumes. The papers on grassland demonstrate the value of herbicides when integrated with cultural methods of sward improvement, and there are contributions to the ecology of rushes, buttercups and wild oats. The

extent of the field covered by the conference may be judged from the subjects of other papers which include crop desiccating agents, arboricides, and weed control for sports turf, forest nurseries, farm ditches and roadside verges. A section is devoted to application machinery and its improvement and there is a comprehensive review by F. R. Horne of weed seeds in relation to crop production.

Dr. J. Philp discusses the harmful effects of weeds and measures for their destruction in a survey of the weed problems in vegetable crops. Chemical methods do not at present go very far towards solving these problems, and he concludes that more ecological research is required, besides evaluation of the newer herbicides. The scope for the use of herbicides in fruit culture is dealt with by Dr. F. R. Tubbs who quotes figures for the cost of weed control in relation to total labour costs for different fruits. He shows that in tree fruits weeds are not a serious economic factor, although herbicides would be useful in certain instances. In bush fruit and strawberries there is greater scope for chemical control, particularly of grasses, bindweed and thistle.

G. E. Barnsley describes a field trial with chemicals for stripping hops in which an oil emulsion containing dinitrocresol caused no injury to mature hop plants and gave results commercially comparable with hand-stripping. Dr. E. K. Woodford reports progress with the herbicide CMU and collates preliminary results for vegetable and other crops. Many annual weeds are readily controlled, and there is a possibility of selective effect in certain relatively tolerant crops. Results of tests with various chemicals on sugar-beet described by C. Parker are of horticultural interest by reason of their possible application to red beet; A. L. Abel summarizes experimental work with sodium trichloroacetate for the control of couch grass.

The Proceedings also contain the reports of sub-committees. That of the Recommendations Sub-Committee is especially valuable as it tabulates the reactions of 174 weed species to four herbicides and lists treatments recommended for the different crops. This is the first time that such a comprehensive, authoritative and up-to-date guide has been available in Great Britain. The volume is fully indexed and is produced in handy and readable size by the litho-offset process.

A permanent organization has now been set up so that future conferences can be held. Meanwhile, the first Proceedings set a high standard both in subject-matter and presentation, and the organizers deserve the gratitude of all to whom weeds are a source of concern.

H.A.R.

INSECT, FUNGUS AND WEED CONTROL. By E. R. de Ong. (London: Thames & Hudson. 1953. Pp. 393, illus. Price 52s. 6d.)

Nowhere has the development of chemicals for the control of insects, fungi and weeds been more intensive than in the U.S.A., where many thousands of proprietary materials are in commercial use. This book is designed to provide an up-to-date guide on modern methods for farmers, market gardeners, foresters, entomologists, veterinary workers, public health authorities and students. It includes chapters on organic and inorganic insecticides, fungicides and weedkillers, the physical properties of sprays and dusts, forest insects and diseases, livestock pests, household insects and rodents, industrial and storage problems and on equipment used in the application of control measures. The book brings together the results of field experience and research, up to 1952, compiled mainly from publications such as the *Journal of*

Economic Entomology, Agricultural Chemicals and bulletins of the U.S. Department of Agriculture and Experiment Stations.

Written almost exclusively from the American viewpoint (there are six references to British work out of some six hundred and fifty), the book places emphasis on chemical control and purposely makes little attempt to deal adequately with wider considerations of interest to the biologist or toxicologist. The author does not assess the information he gives or make recommendations from it, pointing out that the procedure to be adopted, even to the choice of a chemical for a particular purpose, must be determined in the light of local conditions and experience. Little help is given to the general reader in discerning the main trends in the development of the subject. The practice of referring to the chemical and common names of active ingredients and to the proprietary names of compounded materials without differentiation is hardly likely to dispel confusion, while topics of special interest at the present time receive scant attention. Systemic insecticides and fungicides are poorly reported ; bisdimethylaminophosphonous anhydride and octamethylpyrophosphoramide, chemical synonyms for the compound better known as schradan, are described (pp. 80 and 106-7) as separate materials with indications of differing activities against mites. Glyoxalidine derivatives, the subject of American publications since 1946, are dismissed with the statement that, while promising, they are not generally used. A useful discussion of the physical properties of sprays is marred by the indifferent treatment of adjuvants such as wetters.

In a book such as this, containing much detailed information, a comprehensive and easily-used index is indispensable. Here, the index is totally inadequate and subjects of importance and interest discussed in the text receive no mention. The reader interested, for example, in Federal tolerances for spray deposits on crops will find no reference to the Table given on p. 25. Emulsifiers, referred to on p. 16 and discussed on pp. 161-3, are omitted from the index, as is also any reference to the abrasion of equipment, dealt with on pp. 23-4. The important question of the effect of particle size on the efficiency of insecticides and fungicides is examined on pp. 20-22 ; no reference is made in the index to the particle size of insecticides, and the citation for fungicides is misleading. Calcium arsenite is included in the index, but not calcium arsenate although three references are given to this compound under " Arsenates, calcium ". There is no assurance, however, that an index search of all headings under which a subject might be included will reveal all discussions of it in the text. The weedkiller MCPA, a British discovery that has given inestimable service to crop protection throughout the world, is dismissed in a few lines on p. 243 and does not appear in the index.

While no doubt of considerable value to American users, the book will come as a disappointment to other workers interested in the general principles and intricacies of insect, fungus and weed control.

J.T.M.

PUBLICATIONS RECEIVED.

BOOKS ON AGRICULTURE AND HORTICULTURE. Ministry of Agriculture Bulletin No. 78. (H.M. Stationery Office. 1954. Pp. 90. Price 3s. (3s. 2d. by post).)

THE FARM TRACTOR. Ministry of Agriculture and Fisheries. (H.M. Stationery Office. 1954. Price 1s. 9d.)

NOTICE TO CONTRIBUTORS

1. The **Journal of Horticultural Science** is an official organ of the Horticultural and Agricultural Research Station, Long Ashton, Bristol, and the Horticultural Research Station, East Malling, Kent.

The Publication Committee welcome horticultural papers from all other sources.

2. All **manuscripts** should be in double-spaced typewriting, with a good margin, and should be addressed to the Editors, East Malling Research Station, near Maidstone, Kent, England. Papers must be written concisely. Historical reviews should be as short as possible and only such references to literature as bear directly on the subject should be included. Tables and illustrations, if any, must be only such as are absolutely essential for clear presentation.

3. Authors of papers containing extensive **numerical observations** should consult the recommendations of the British Association Committee on Biological Measurements, 1927, obtainable from Burlington House, London, W.1. Price 6d. Arrangements have been made whereby original data too extensive for complete publication may be deposited at the British Museum (Natural History), London, S.W.7, or with the Royal Society of Edinburgh, 22 George Street, and thus be available for consultation by other workers. Full bibliographical reference to the publication in which the results are summarized must be supplied with the data.

4. Each paper must conclude with a concise and critically correct **summary** of its actual content. It should contain any new or verified constants as well as any other critical data of permanent value but not tables or graphs. Any organism mentioned should be given its scientific name.

5. Where a paper is of a highly technical nature it should be preceded by a brief **synopsis**, in which its contents are simply and clearly stated for the benefit of non-technical readers.

6. **References to literature** may be by numbers (in brackets) in the text corresponding to a numbered list at the end of the paper or by the Harvard system (author's name and date of publication). By either method, the papers cited should be listed alphabetically according to authors' names, followed by the date of publication. The title of the paper should next be given in full, followed by contracted, but strictly intelligible, title of source of publication, the volume and page numbers. Authors are responsible for the accuracy of their lists of references and should check them carefully in both typescript and proof.

7. The **scientific names** given in the "List of Common British Plant Diseases", published by the British Mycological Society (Cambridge University Press, 1944) and "Common Names of British Insect and other Pests", published by the Association of Applied Biologists (The Mendip Press Ltd., Bath, 1947) must be employed.

8. Authors in this country will be supplied with slip **proofs** of their papers; these they should correct with care immediately on receipt and return without delay, together with the original manuscript. Page proofs are not usually supplied to authors. Typographical errors, if any, should be corrected; small verbal alterations are permissible but substantial changes may not be made. Overseas authors should be willing to accede to editorial treatment of their contributions, if necessary, limited to methods of presentation, and leave proof correction to the Editors.

9. A single author will receive twenty-five **reprints** of his article free of charge. Special arrangements as to number of free reprints apply to papers by more than one author.

Additional reprints can be purchased at fixed prices, if ordered at the time of returning the corrected slip proofs and original manuscript.

10. The **copyright** of all articles and illustrations published becomes the property of the *Journal*, but Abstracting Journals may reprint the summaries, or translations of them, if desired. For permission to reprint more than this, application should be made to the Editors.

The publication of a paper in the *Journal* does not imply responsibility for, or agreement with, any statements or views expressed therein, but merely that the paper has been deemed to be of sufficient scientific interest to merit inclusion.

CONTENTS

PAGE

Observations on the Shoot Growth of the Cultivated Strawberry Plant. By C. G. GUTTRIDGE 1

The Effects of Chlordane and Toxaphene on Mitosis in Roots of the Onion (*Allium cepa* L.). By MARY E. SCHOLES 12

Apple Rootstock Studies: Malling-Merton Rootstocks. By A. P. PRESTON 25

Some Effects of Temperature and Daylength on Flowering in the Chrysanthemum. By DAPHNE VINCE 34

Steam Pressure in Soil Sterilization. II. Glasshouse *in situ* Sterilizing. By A. C. BUNT 43

Strawberry Yellows in the Variety Auchincruive Climax. By A. F. POSNETTE and R. CROPLEY 56

Studies in the Development of the Strawberry. III. Flower-bud Initiation and Development in Large-fruited Perpetual ("Remontant") Strawberries. By MARGARET ROBERTSON 62

Book Reviews 69

HORTICULTURAL ABSTRACTS

A Quarterly Journal for the research worker and progressive grower, issued regularly since 1931 by the COMMONWEALTH BUREAU OF HORTICULTURE AND PLANTATION CROPS at East Malling Research Station.

CONTENTS. A digest of world research on the problems of the fruit-, vegetable- and flower-grower, of the tobacco-producer and of the tropical and sub-tropical planter.

SUBSCRIPTION RATES. Subscriptions, which should be sent to *C.A.B., Central Sales Branch, Farnham House, Farnham Royal, Slough, Bucks:* Foreign, 50s. a volume or $7.00; British Commonwealth of Nations, 40s. a volume. Single copies 15s. or $2.10.

PRINTED BY HEADLEY BROTHERS LTD 109 KINGSWAY LONDON WC2 AND ASHFORD KENT